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Palynalogy and Biostratigraphy of some Upper Devonian Deposits of Western New York State and Northern Pennsylvania, U.S.A.

Ahmed, S

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PALYNOLOGY AND BIOSTRATIGRAPHY OF SOME UPPER DEVONIAN DEPOSITS OF WESTERN NEW YORK STATE AND NORTHERN PENNSYLVANIA, U. S. A.

by

SARFRAZ AHMED

A thesis submitted for the degree of Doctor of Philosophy,

King's College, University of London.

March, 1978

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ABSTRACT

Palynological and biostratigraphical studies have been made of six sections extending over 4,000 sq. Kms. through the Upper Devonian in western New York State and northern Pennsylvania, U.S.A. Sediments from this region, which represents the stratotype for the Devonian of North America, have disclosed profuse assemblages of spores and microplankton, the former constituting the basis of the present investigations.

Sixty-two samples from four formations have been analysed, all of which contained palynomorphs. The sequence of these palynomorphs indicates complex relationships between marine and continental facies. Acritarchs have been recorded from throughout the sequence apart from the lower part of the Ellicott Member of the Chadakoin Formation but these are used only as environmental indicators and have not been dealt with monographically.

The miospores examined are given systematic treatment, illustrated and a range chart has been constructed of their stratigraphical occurrence. Ninty-seven spore forms have been encountered which can be attributed to 33 genera of trilete sporae dispersae; of these eleven species and four varieties are new; sixteen new combinations and one new name is proposed; seven other forms are present but are insufficient numerically to be proposed as new. Three distinct miospore assemblage zones, termed Streelispora catinata - Ancyrospora neograndispinosa, Synorisporites flexuosus - Auroraspora varia and (the youngest) Vallatisporites vallatus var. hystricosus - Retispora lepidophyta, have been recognized within the studied sequence.

Miospore forms of the genus Auroraspora have been found particularly useful in this study because these are abundant and show stratigraphical changes.

Upper Senecan to Chautauquan Series of New York State and Pennsylvania have been investigated which are equivalent to Upper Frasnian and Famennian stages in Europe.

Within the area studied correlations are made between sediments of diverse non-marine and marine facies. Stratigraphical and phytogeographical distributions of the Upper Devonian miospores are described and the implications of their distribution patterns are discussed.

A correspondence between the North American miospore assemblages and those from other continents support the concept of an essential cosmopolitan floral elements. However, in detail there are some interregional differences.

TABLE OF CONTENTS

Title page	I
Abstract	2
Table of contents	4
List of text figures	9
List of tables	II
Acknowledgements	I3
Introduction	I4
Nature of research	I5
Chapter I: Stratigraphy and Palaeontology	I7
Devonian System	I9
Upper Devonian (Senecan) Series	I9
Seneca Group	I9
Java Formation	I9
Pipe Creek Shale Member	I9
Hanover Shale Member	2I
Upper Devonian (Chautauquan) Series	2I
Arkwright Group	22
Canadaway Formation	22
Dunkirk Shale Member	22
South Wales Shale Member	24
Gowanda Shale Member	24
Laona Siltstone Member	25
Westfield Shale Member	25
Shumla Siltstone Member	25
Northeast Shale Member	26
Chadakoin Formation	26
Dexterville Member	27
Ellicott Member	27
Conewango Group	28
Cattaraugus Formation	29

	Structural Geology	30
	Historical Geology	30
	Sedimentary Structures	31
	Previous research on stratigraphy and palaeontology	32
Chapter 2:	Previous palynological investigations	34
Chapter 3:	Techniques	44
	Single grain mount	45
	Scanning electron microscopy	45
	Counting	47
	Method of study	48
Chapter 4:	Morphographical terminology	49
	Glossary of terms used	50
Chapter 5:	Nomenclature and classification of spores	62
Chapter 6:	Systematics	70
	Infraturma: LAEVIGATI	72
	Calamospora	72
	Leiotriletes	75
	Punctatisporites	77
	RETUSOTRILETI	81
	Retusotriletes	81
	Apiculiretusispora	88
	Pulvinispora	91
	Aneurospora	94
	APICULATI	101
	Hystriccsporites	101
	Geminospora	104
	Verrucosisporites	105
	Acanthotriletes	107

	Dibolisporites	II0
	Raistrickia	II3
	Biharisporites	II6
Infraturma: MURORNATI		II7
	Camptotriletes	II7
	Convolutispora	II9
	Emphanisporites	I24
	Dictyotriletes	I26
CINGULATI		I28
	Knoxisporites	I28
	Lophozonotriletes	I33
	Vallatisporites	I34
CRASSITI		I38
	Ambitisporites	I38
	Streelispora	I40
	Synorisporites	I42
ZONATI		I49
	Samarisporites	I49
	Spinozonotriletes	I54
MONOPSEUDOSACCITI		I56
	Grandispora	I56
	Calyptosporites	I6I
	Rhabdosporites	I64
	Retispora	I66
	Spelaeotriletes	I70
	Auroraspora	I73
INCERTAE SEDIS		I98
	Ancyrospora	I98

Chapter 7: Biotratigraphy 206

Description of miospore assemblage zones 210

Comparative palynology within the areas studied 223

Comparative palynology of the Bush Hill and Brick Quarries Sections 223

Comparative palynology of the Bush Hill and Hamlet Quadrangle Sections 227

Comparative palynology of the Bush Hill and Pope Hollow Sections 230

Comparative palynology of the Bush Hill and Lewis Run Sections 236

Chapter 8: Comparison of miospore assemblages 241

I. Comparison of miospore assemblages with areas outside North America 242

Belgium 242

The British Isles 245

Poland 246

Soviet Union 247

North Africa 249

Astralia 250

2. Comparison of miospore assemblages with those from other parts of North America 253

The U. S. A. 253

Canada 257

Chapter 9: Geographical variations in the miospore assemblages 261

Introduction 262

Salient features of the Upper Devonian miospore assemblages 265

Result and discussion 271

Conclusions 279

Systematics plates: I - 22 283

References 328

Appendix: Sampling localities and microfossil data 350

LIST OF TEXT FIGURES

I.I. General map showing areas studied I8

I.2. Generalized stratigraphical succession showing the horizons sampled 20

I.3. Development of stratigraphical nomenclature 23

4.I. General features and variations of spores in equatorial and longitudinal views 5I

4.2. Different shapes of spores 53

4.3. Tetrad mark and associated features 55

4.4. Structural features and exine organization 57

4.5. Sculptural elements and patterns 60

6.I. Sculptural elements of *Dibolisporites* sp. III

6.2. Sculptural elements of *Vallatisporites vallatus* var. *hystricosus* I35

6.3. Distribution of sculptural elements in *Vallatisporites vallatus* var. *hystricosus* I37

6.4. Distal ornament in *Synorisporites flexuosus* I44

6.5. Sculptural elements of (a) *Samarisporites kedoae* and (b) *Samarisporites* sp. cf. *S. kedoae* I52

6.6. Sculptural elements of *Calyptosporites perclarus* I63

6.7. Histogram showing the percentage ratio of spore body radius to pseudosaccus radius in the two species of *Auroraspora* I82

6.8. Comparison of size variation in the two species of *Auroraspora* I87

6.9. Diagrammatic sketches illustrating the morphological variations in different species of the genus *Auroraspora* I94

6.IO. Diagrammatic sketches illustrating the nature of spines in (a) Ancyrospora multifurcata and (b) A. acadensis 200

7.I. Percentage distribution of miospores, acritarchs and unidentifiable palynomorphs in the samples investigated 209

7.2. Variations in species number from eleven palynological samples 220

7.3. The geographical locations of the sections investigated 222

9.I. Proportion of species which typify the multifurcata suite in the sequence in New York State and Pennsylvania 273

9.2. The distribution of the floral suites and Retispora lepidophyta plotted on the pre-drift continent positions suggested by Smith, Briden and Drewry (text fig. II, I973) 275

9.3. The distribution of the floral suites plotted on the pre-drift continent positions (Middle Devonian) suggested by McElhinney after Oliver I976 276

9.4. The distribution of the floral suites plotted on the present continent positions 277

LIST OF TABLES

2.I. Ranges of selected miospores in the Upper Devonian of Belgium, recorded by Streel 38

2.2. Miospore zonation schemes in the Upper Devonian - Lower Carboniferous assemblages established by Streel (I966), Neves et al. (I972) and Clayton et al. (I974) 42

3.I. Summary of laboratory procedure for extracting spores 46

5.I. The suprageneric classification proposed by Potonié & Kremp (I954) 66

5.2. The suprageneric classification proposed by Dettmann (I963) 66

5.3. The suprageneric classification proposed by Neves & Owens (I966) 68

5.4. The suprageneric classification proposed by Smith & Butterworth (I967) 68

6.I. Size range and stratigraphical distribution of Retispora lepidophyta and R. lepidophyta var. granda in the samples investigated I68

7.I. Stratigraphical ranges of spores, and assemblage zones in the Upper Devonian of New York State and Pennsylvania 2II

7.2. Stratigraphical ranges of miospore forms observed in marine strata 224

7.3. Ranges of the spores recorded from the Brick Quarries and the Bush Hill Sections 226

7.4. Ranges of the spores recorded from the Bush Hill and the Hamlet Quadrangle Sections 228

7.5. Ranges of the spores recorded from the Bush Hill and the Pope Hollow Sections 232

7.6. Ranges of the spores recorded from the Bush Hill and the Lewis Run Sections 235

7.7. A checklist of spores observed from five of the sections 237

7.8. Numerical comparison of species from the Bush Hill sequence with those from four of the sections investigated 239

8.I. A correlation of the Upper Devonian sequences of New York State and Pennsylvania with those from other parts of the world 244

8.2. Sequences of Ohio, investigated by Winslow (I962) 253

8.3. A comparison in number of species from the Upper Devonian of New York State and Pennsylvania with those from other parts of the world 254

9.I. Regional comparison of selected Upper Devonian miospore species 264

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INTRODUCTION

The western part of New York State is well known for its many geological features. "Since Devonian studies began, the New York and Appalachian area has been famous for the wealth of its faunas, the diversity of its facies, the incredible stratigraphical precision which the undisturbed and well exposed sequence allows, and for the easterly tract of thick sediments which gave rise to the term 'geosyncline'". (House 1973, p. 270). House (loc. cit.) concludes "As an area in which relations between terrestrial and marine facies can be elucidated, the New York sequence must surely be the only complete succession in the world which can be regarded as forming an international standard."

Many previous workers have published papers on specific stratigraphic and palaeontologic topics within the area (see text figs. I.I and I.3.). The comprehensive, up to date information of Upper Devonian geology of the area investigated are given by Tesmer (1963, 1967, 1975) who conducted intensive field investigations in western New York State. Three groups are recognized, in ascending order, the Seneca, Arkwright and Conewango. The groups in turn are divided into formations and subdivided into members (see text fig. I.2.). Tesmer (loc. cit.) regards formations to be of regional extent, often traced through several counties, while members in the clastic sequence are often of more local occurrence. This scheme of stratigraphic subdivision has been adopted in the present work. The Upper Devonian strata outcropping in the area are together approximately 670 metres thick that are essentially clastic, for the most part interbedded shales, siltstone but with increasing percentage

of sandstone, conglomerate towards the top. Marine invertebrate are quite abundant but plant and fish are also represented at various horizons. Conodonts are considerably more frequent than ammonoids. Frasnian goniatites of Europe are often represented by the same genera and sometimes identical species in North America.

Spores are particularly useful in that they may be deposited in large numbers, in both fresh water and marine sediments, thus providing a useful link between continental and marine stratotypes.

In general the preservation of palynomorphs; miospores, acritarchs, chitinozoans, scolecodonts is poor. Miospore assemblages especially in the Java and lower part of Canadaway Formation are in an inferior state of preservation, when compared with the nature of preservation in younger beds. Some of the specimens are difficult to identify, since they are squashed beyond recognition; other are brittle in nature. Occasionally well preserved specimens are found in upper part of the Canadaway Formation and more infrequently excellently preserved ones in the Chadakoin and Cattaraugus Formations. Chitinozoans, and scolecodonts have been illustrated and acritarchs have also been illustrated and counted, but they are not described systematically herein, since many of them can be attributed to existing species.

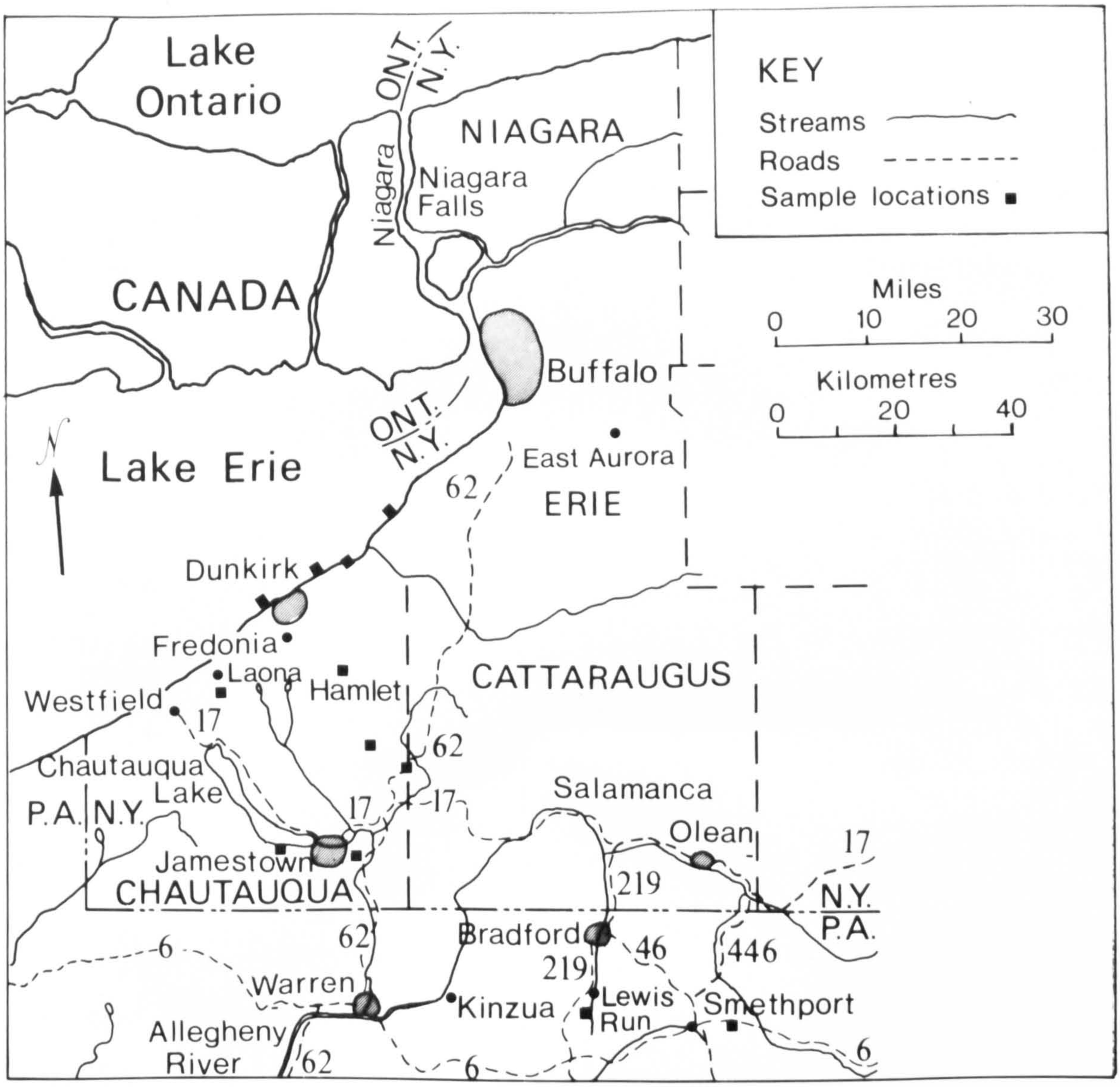
NATURE OF RESEARCH

The objective of this investigation was to obtain and describe miospore assemblages of some Upper Devonian deposits, the Java, Canadaway, Chadakoin and Cattaraugus Formations of western New York State and northern Pennsylvania, and secondly, to utilize their stratigraphic potential both for local and basinal correlation. A successful more precise correlation than has been achieved before

might be expected to lead to a greater understanding of the palaeoenvironments. Scanning electron microscopy has been carried out as a supplementary method of investigation and illustration to optical microscopy.

CHAPTER I

STRATIGRAPHY AND PALAEONTOLOGY



Text fig 1.1 Location of sampling areas

STRATIGRAPHY AND PALAEONTOLOGY

DEVONIAN SYSTEM

UPPER DEVONIAN (SENECAN) SERIES

The rocks dealt with in this study from Pipe Creek Shale Member to the top of the Hanover Shale Member are of Senecan age which correspond in part with the Frasnian series of Europe.

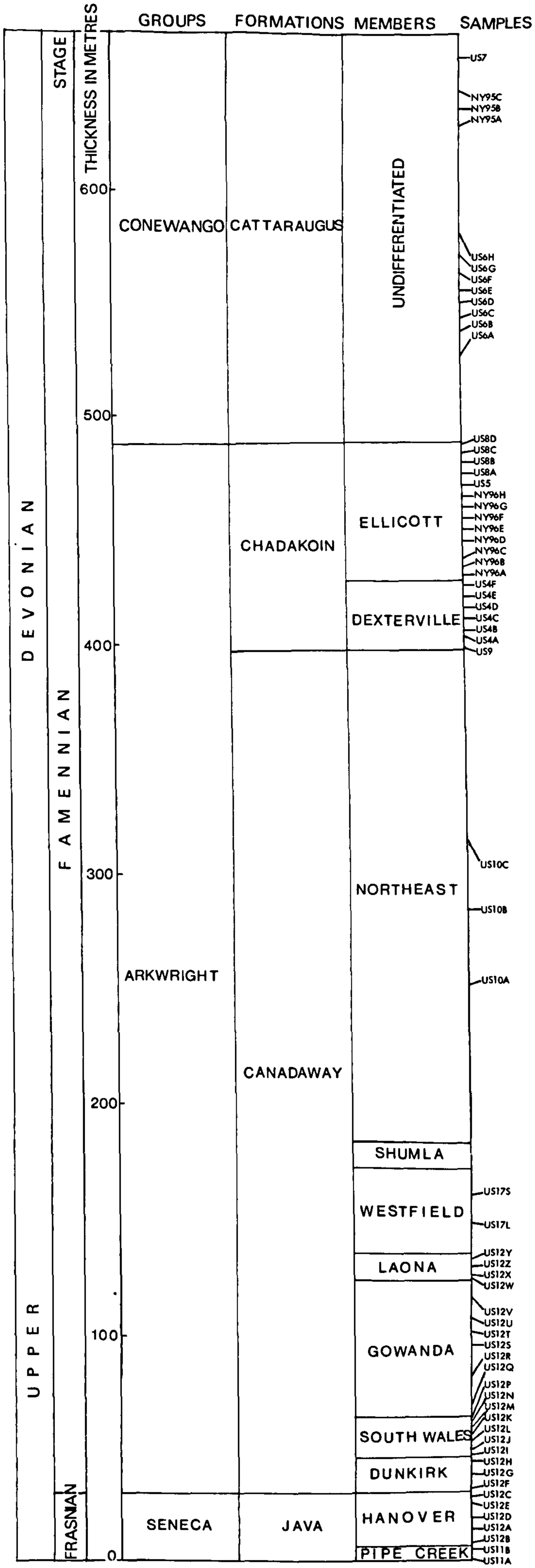
SENECA GROUP

This lithostratigraphic unit (Seneca Group Clark & Schuchert 1899, p. 874) is composed of four formations. In ascending stratigraphic order these are; Genese, Sonyea, West Falls and Java. Each of these are further divided into various members.

JAVA FORMATION

In the present study Java Formation (Pepper & de Witt 1950; de Witt 1960, pp. 1933-1936) is investigated which is divided into an older Pipe Creek Shale and overlying Hanover Shale Member. The Java Formation varies in thickness from 27-35 metres. This unit consists of greenish grey to black shale with some limestone layers and zones of calcareous nodules.

PIPE CREEK SHALE MEMBER (Chadwick 1923, p. 69) is a greyish-black shale that varies from a few inches to 6 meters in thickness. The name is derived from Pipe Creek Glen, near West Falls, Erie County, New York. This rock unit lies between older Angola or



Text fig.1.2. Generalized stratigraphical succession showing the horizons sampled

Nunda Shale and Younger Hanover Shale Member. Exposures are observable along Lake Erie about four miles west of Silver Creek. Fauna includes conodonts and the fish Leptœteus angustus.

HANOVER SHALE MEMBER The name Hanover Shale is introduced by Hartnagel (1912, p. 76) for the rock unit beneath the black Dunkirk Shale (text fig.I.3.). The Hanover consists of grey to greenish-grey, grey silty shale, thin limestone beds, and many zones of calcareous nodules that occur in a great variety of shapes and vary from a half an inch to a metre in thickness. Pepper and de Witt (1950) state that Hanover sediments were derived from the southeast, in the state of Pennsylvania, as the sediments thicken in that direction. Exposures outcrop in Lake Erie Cliffs east of Dunkirk and also exposed in Cattaraugus Creek from Irving to near Versailles. Conodonts include Palmatolepis subrecta and Ancyrognathus euglyphea reported by Hass 1958, p. 766. De Witt & Colton (1953) report the cephalopod Monticoceras cf. pattersoni from Hanover Shale Member.

UPPER DEVONIAN (CHAUTAUQUAN) SERIES

The Chautauquan Series is represented by rock exposures in Chautauqua County, New York (Clark & Schuchert 1899, p. 874). All strata from the base of the Dunkirk Shale Member of the Canadaway Formation to top of the Cattaraugus (and Oswayo) Formation belong to the Chautauquan (Famennian) age. Tesmer (1967, p. 262) placed all the four groups of Upper Devonian of Southwestern New York State in the single Chautauquan Series, while in a recent publication Tesmer (1975, pp. 30 and 32) considers all sediments from the base of Genesee Formation to top of Java Formation to be of Senecan age and those overlying (from base of the Dunkirk Shale Member of the Canadaway Formation to top of the Oswayo Formation)

to be of Chautauquan age. These series (Senecan and Chautauquan) correspond with the Frasnian and Famennian Series of Europe.

ARKWRIGHT GROUP

The term Arkwright Group is proposed and described by Tesmer (1955, pp. 9-18) for 450 metres of strata between the base of Dunkirk Shale Member of the Canadaway Formation to the top of the Ellicot Shale Member of the Chadakoin Formation. The type locality is in Arkwright Township, Chautauqua County, in the Dunkirk and Cherry Creek quadrangle. This rock unit consists of grey to black shale interbedded with light grey siltstone. The Arkwright Group consists, in ascending order, of the Canadaway and Chadakoin Formations.

CANADAWAY FORMATION

At the base of the Arkwright Group is the Canadaway Formation (Chadwick 1933, pp. 355, 357), about 300 metres of grey to black shale with various zones of concretions and septaria and many siltstone beds. The type locality is along Canadaway Creek, Dunkirk quadrangle. Pepper & de Witt (1951) and de Witt & Colton (1953) recognized a 'Perrysburg' Formation which consists of the Dunkirk, South Wales and Gowanda Members, among others. As the 'Perrysburg' Formation has an ill-defined top, Tesmer (1955, pp. 9-10) retained the term Canadaway Formation which includes the Dunkirk (oldest), South Wales, Gowanda, Laona, Westfields, Shumla and Northeast Shale Members.

DUNKIRK SHALE MEMBER The name Dunkirk was proposed by Clarke (1903, p. 24) for the olive grey to black shale containing some pyrite nodules and septaria that vary from a few inches to less than

Hall 1839, 1840, 1843 Beck 1840 Horsford 1840 Mather 1840	Rogers, 1858 Lesley 1875, 1876 Platt 1875 White 1878	Ashburner 1880 Carll 1880, 1883	Williams 1887 Clarke 1899, 1902 Clarke & Schuchert 1899 Luther 1902	Clarke 1903 Glenn 1903 Glenn & Butts 1903 Luther 1903	Butts 1908, 1910	Girty 1904 Hartnagel 1912	Chadwick 1919, 1923, 1924
Catskill	Catskill Chautauqua cgl.	Venango Hommer Run Panama Tanners Hill	Cattaraugus Wolf Creek cgl.	Cattaraugus		Cattaraugus Panama Wolf Creek	Cattaraugus Wolf Creek-Panama
Chemung	Chemung			Chemung	Chemung	Chautauquan Chemung	Chautauquan Chadakoin
Laona Gardeau	Portage		Cuba Rushford Long Beards Riffs Senecan Wiscoy	Portage Portland Dunkirk Silver Creek		Cuba Shumla Senecan Portage Laona Gardeau Dunkirk Hanover	Volusia Cuba Northeast-Machias Shumla Westfield Laona-Rusford Gowanda Dunkirk-Canaseraga Senecan Hanover-Wiscoy Pipe Creek

TEXT FIG. 1.3. DEVELOPMENT OF STRATIGRAPHICAL NOMENCLATURE (MODIFIED FROM TESMER 1975).

Chadwick 1933	Caster 1934 Chadwick 1935a Cooper et al. 1942	Woodruff 1942	Pepper and de Witt 1951 de Witt 1960	Rickard 1964 N.Y. State Geol. Survey	Oliver et al. 1969 U.S. Geol. Survey	Tesmer 1975
Cattaraugus	Venango Amity Panama-Wolf Creek	Cattaraugus		Venango-Cattaraugus	Cattaraugus Fm.	Cattaraugus Fm.
Wolf Creek Chautauquan	Chautauquan					
Chadakoin (inc. Hinsdale)	Conneaut Chadakoin Dexterville Lillibridge	Conneaut Hinsdale		Conneaut Group "Chadakoin" Fm.	Chadakoin Fm.	Arkwright Group Chadakoin Fm.
Volusia-Girard Cuba Canadaway Northeast-Machias Shumla Westfield-Rushford Laona	Girard Cuba Canadaway Northeast Shumla Westfield Laona	Canadaway Cuba		Canadaway Group Northeast Shumla Westfield Laona "Perrysburg Fm. Gowanda South Wales Dunkirk	Northeast Westfield Perrysburg Fm. Gowanda Mem. South Wales Mem. Dunkirk Mem.	Canadaway Fm. Northeast Sh. Mem. Shumla Slts. Mem. Westfield Sh. Mem. Laona Slts. Mem. Gowanda Sh. Mem. S. Wales Sh. Mem. Dunkirk Sh. Mem.
Gowanda-Canadea	Gowanda	Rushford Canadea	Laona-Rushford Perrysburg Gowanda South Wales			
Dunkirk-Canaseraga Senecan	Dunkirk Senecan	Dunkirk	Dunkirk	Senecan Series Java Group Hanover Pipe Creek	Senecan Series Java Fm. Hanover Mem. Pipe Creek	Senecan Series Java Fm. Hanover Sh. Mem. Pipe Creek
Hanover-Wiscoy Pipe Creek	Chemung Hanover Pipe Creek		Java Hanover Pipe Creek			

two metres in diameter. Some small calcareous nodules are also present. Tesmer (1975, p. 34) states that "the black shales often exhibit a petroleum odour, especially when freshly broken." The lower contact between the light to medium grey Hanover Shale and the greyish-black or black shales of the Dunkirk is sharp and easily recognized. Outcrops of the members may be observed along Lake Erie shore between Van Buren Point and Point Gratiot in the city of Dunkirk, Walnut and Silver Creeks south of the village of Silver Creek. Pyritized algae, carbonized plant stems and conodonts such as Palmatolepis subrecta have been reported.

SOUTH WALES SHALE MEMBER Pepper & de Witt (1951) subdivided the Gowanda of Chadwick (1919, p. 157) into two units, an older South Wales and a younger Gowanda (text fig.I.3.). This unit consists mostly of medium light grey to medium grey shales. Some greyish-black shales, grey silty shales and ripple-marked light grey siltstones are present. Beds of calcareous concretions, sometimes up to a metre in diameter, also occur. The outcrops of the member are observable along Lake Erie near Van Buren Point, along Canadaway Creek in Dunkirk Township, Walnut and Silver Creeks in the town of Hanover. In addition to algae, conodonts Ancyrognathus bifurcata and Palmatolepis glabra have been reported.

GOWANDA SHALE MEMBER Originally, Chadwick (1919, p. 157) included the strata between the top of the Dunkirk Shale and the base of the Laona Siltstone in the Gowanda. Pepper & de Witt (1951) proposed a division of the original unit into an older South Wales Member and a younger restricted Gowanda Member. This member contains medium light grey to greyish black shale with some interbedded light grey siltstone beds. Also present are many zones of calcareous concretions and septaria of various shapes. Exposures of the member

can be traced along the Lake Erie shore between Barcelona and Portland, in Canadaway Creek at Fredonia, in Walnut Creek north of Forestville and in Cattaraugus Creek near the village of Gowanda. Some pelecypods and cephalopods have been observed. Conodonts include Palmatolepis glabra, P. perlobata and P. subperlobata.

LAONA SILTSTONE MEMBER The unit was named Laona Siltstone by Beck (1840, p. 57) for the rocks overlying the Gowanda Shale Member. The member varies from a few inches to six metres in thickness and consists of light grey quartzose siltstone beds up to a few inches in thickness, with some interbedded grey shale and silty shale. Rocks can be seen along Lake Erie at Barcelona, Canadaway Creek at Laona, Walnut Creek at Forestville, and in Silver Creek in Hanover Township. The Laona fauna consists largely of brachiopods, although pelecypods are moderately abundant.

WESTFIELD SHALE MEMBER Chadwick (1923, p. 69) was the first to use the name Westfield shale (text fig.I.3.) for a series of mostly medium grey shales and a few light grey siltstones between the Laona and overlying Shumla siltstones. The type locality is along Chautauqua Creek at the village of Westfield, New York. The member has been traced in Lake Erie Cliffs between Barcelona and the Pennsylvania State line, in Canadaway Creek between Laona and Shumla, in the headwaters of Walnut Creek near Forestville and in Chautauqua Creek between Barcelona and Westfield. Following conodonts have been recovered: Ancyrognathus bifurcata, Neoprioniodus mutabilis, Palmatodella delicatula, Palmatolepis glabra, P. perlobata and P. subperlobata.

SHUMLA SILTSTONE MEMBER Clarke (1903, p. 25) assigned the name Shumla to the beds exposed at shumla, New York. The Shumla varies in thickness from less than a meter to almost nine meters. It

usually exhibits a sharp contact with the underlying Westfield Shale Member but grades upward into the shales of the Northeast Member. Light grey quartzose siltstone beds predominate. Outcrops include the Lake Erie Cliffs near the New York-Pennsylvania state line, Chautauqua Creek at Westfield, Canadaway Creek at Shumla. The conodonts Ancyrognathus bifurcata, Neoprioniodus mutabilis, Palmatolepis glabra, P. perlobata, P. subperlobata, Polygnathus semicostata have been reported.

NORTHEAST SHALE MEMBER The Northeast Shale was named by Chadwick (1923, p. 69) for a rock unit varying 120-210 metres in thickness. The member consists of medium grey shales and silty shales with considerable interbedded grey siltstone beds at various horizons. Near the Pennsylvania state line, it sometimes exhibits well developed cone-in-cone structure. Outcrops are observable along Canadaway Creek in Arkwright township and also along little Chautauqua Creek in the town of Westfield. The fauna increase in abudnance towards the top of the member as well to the east. In addition to brachiopods, bryozoans, pelecypods and crinoid columnals, conodonts are also present. Hass (1958, 765-769) reports the presence of following conodonts, from the type locality in Pennsylvania, Palmatolepis glabra, P. perlobata, P. quadrantinodosa.

CHADAKOIN FORMATION

The name Chadakoin to these strata was given by Chadwick (1923, p. 69) while Tesmer (1955, p. 10), called the Chadakoin Formation (text fig.I.3.). Glenn (1903, pp. 968-971) originally called "Chemung beds". Caster (1934, pp. 62-69) divided the Chadakoin into Lillibridge Sandstone, Dexterville Shale and Ellicott Shale Members . Tesmer (1955, p. 14) does not recognize the "Lillibridge" Sandstone Member as a distinct strati-

graphic unit. Tesmer (1955, p. 10; 1963, pp. 35-41; 1967, p. 266) divides the Chadakoin Formation into an older Dexterville Member with the index fossil 'Pugnoids' duplicatus and a younger Ellicott Member. Both are lithologically identical although the Dexterville usually contains a higher percentage of grey siltstones than the Ellicott in which grey shales are more abundant.

Chadwick (1935, p. 351) proposed Conneaut Group for those beds from the base of the Cuba Sandstone to the base of the Wolf Creek (Panama) conglomerate (text fig.I.3.). Thus, Conneaut Group (see geological map of New York, Niagara Sheet, Richard & Fisher 1970) includes the same strata as the Chadakoin Formation (Tesmer 1975, p. 49).

The Chadakoin Formation averages about 90 metres in thickness.

DEXTERVILLE MEMBER The name Dexterville was proposed by Aster (1934, p. 63) for exposures of grey micaeous siltstones and shales containing the brachiopod 'Pugnoides' duplicatus, which are found along the Chadakoin River in a district of east Jamestown. The Dexterville varies from about 12 to 36 metres in thickness and can be recognized at many localities in Chautauqua County including Twentymile Creek in Ripley township, Chautauqua Creek about 4 miles south of Westfield, and along the Chadakoin River in Jamestown. Brachiopods Pugnoides duplicatus, Ambocoelia gregaria, Athyris angelica, Camarotoechia contracta, Cyrtospirifer sp. Productella spp. Strophalosia hystricula and Thiemella tenuilineata have been reported. Also present are various pelecypods such as Mytilarca chemungensis, numerous bryozoans, and crinoid columnals.

ELLICOTT MEMBER The Ellicott Member is also named by Caster (1934, p.66) for exposures of grey shales and interbedded siltstone seen along Hunt Road between Ashville and Jamestown in Ellicott township, Chautauqua County. Pugnoides duplicatus, as index to the

Dexterville, does not extend upward into the Ellicott. The member varies in thickness from 45 to 60 metres. Exposures can also be observed in the headwaters of Twentymile Creek in the town of Ripley, the headwaters of Chautauqua Creek along the Westfield-Chautauqua town line, in scattered exposures at Jamestown, and in tributaries to Conewango Creek in Cherry Creek township. The fauna of the Ellicott is both abundant and varied. Most common are brachiopods such as Ambocoelia gregaria, Camarotoechia contracta, Cyrtospirifer inermis, C. nucalis, Praluctella spp. and Strophalosia hystricula, with accompanying bryozoans and crinoid columnals. Some pelecypods and caphalopods have also been recorded. Conodont species Polylophodonta confluens is reported from Ellicott.

CONEWANGO GROUP

The name Conewango was suggested by Butts (1908, p. 191) and he assigned the Conewango to the Devonian-Carboniferous, the present writer agrees with Tesmer (1975, p. 66) to date Conewangto as Famennian (Chautauquan) as indicated in Caster (1934, chart opposite p. 63) and Hollan (1959, p. 1619). Thus, the Devonian-Mississippian boundary is placed at the contact between the older Devonian Oswayo Shale and the overlying Mississippian Knapp conglomerate.

The type locality for the Conewango Group (Tesmer 1955, p. 8) is along Conewango Creek in the Warren County, Pennsylvania. Here, interbedded shales, siltstones, sandstones and conglomerates are exposed. The Conewango Group contains interbedded grey fine-grained thin-bedded micaceous sandstones, grey siltstones, green sandy shales, red shales and grey shales. The base of the Conewango is often represented by redbeds, or lenses of flat-pebble conglomerates

and buff coarse sandstones. Conglomerates and sandstone lenses are also present higher in the Cattaraugus Formation, which constitutes the lower Conewango in Cattaraugus County.

The base of the group is placed at the first appearance of persistent conglomerate beds or the first appearance of red-beds.

In Chautauqua County, the Conewango Group is undifferentiated while in Cattaraugus County it is divided into two formations, the older Cattaraugus and younger Oswayo Formation.

CATTARAUGUS FORMATION

Clarke (1902, p. 525) introduced the name Cattarugus for red and grey shales interbedded with flaggy siltstone of marine origin. Interspersed are several lenses of buff-coloured sandstones and conglomerate composed of milky quartz pebbles. Tesmer (1967, p. 267) quotes its thickness as much as 195 metres.

Although some conglomerate Members have been described by Tesmer (1963, pp. 45, 47; 1975, pp. 69-73), however, their precise stratigraphic positions are undetermined, consequently, not discussed here.

Outcrops of the Cattaraugus Formation occur in a tributary to Cass Run at the Chautauqua-Cattaraugus County line. Here the Pope Hollow Conglomerate Member (Carll, 1883, p. 180) is exposed at about 570 metres Continuing into Cattaraugus County, conglomerate outcrops are numerous throughout Allegany State Park. Cattaraugus fossils from the Olean quadrangle are listed by Butts (1903, pp. 993-994), including Camarotoechia contracta, Cyrtospirifer tionesta, Leptodesma spp. and Ptychopteria spp. Woodruff (1924, pp. 60-61) lists the plant Barinophyton citrulliforme from the Cattaraugus Formation near Olean.

STRUCTURAL GEOLOGY

Surface structures within the area studied are simple and homoclinal. The regional dip is generally to the south or south-southwest at about 20 to 50 feet per mile. As the dip is very low, the direction and magnitude of dip are changed in places by minor local structures.

No major faults occur within the area, although local minor folds in incompetent beds may occasionally show faults with a displacement seldom exceeding a few inches. Chadwich (1920, p. 120) described a local fault with a throw of 7.5 metres and a heave of about 30 metres which he believed existed along a tributary to Walnut Creek, about a mile northwest of Nashville in the Cherry Creek quadrangle. Tesmer (1963, p. 52) is uncertain whether a fault or a fold is represented, because he (Tesmer) remarks that key horizons are not well represented. Some of the rocks show well developed joint sets. Joints are conspicuous in most of the units and often they occur as two sets nearly at right angles. Upon weathering, the joints are enlarged and bedrock may be separated into large blocks. Such features can be observed in Cattaraugus County and adjacent regions.

The Shumla and Laona Siltstones often have a pronounced petroliferous odour when freshly exposed. These units sometimes serve as oil and gas reservoir rock if they are sufficiently buried and locally permeable. However, the oil and gas fields seem more related to variations in permeability than to any structures which can be measured at the surface.

HISTORICAL GEOLOGY

During the late Devonian time most of New York and adjacent areas were covered by a shallow sea. The shallow depth is indicated

by several features, such as ripple marks and fossil assemblages (sphaeromorphic type acritarchs). The presence of subangular to angular grains of sediment suggests fairly rapid deposition. The bulk of these Upper Devonian sediments was derived from land to the east and southeast, classically called Appalachia.

As the lower Canadaway formed, alternate deposits of black and grey muds accumulated to a thickness of several hundred feet (Dunkirk, South Wales, Gowanda). The organic-rich black mud environment (to the west) and the grey mud environment (to the east) oscillated back and forth with time, causing an intertonguing of these two facies. Upper Canadaway units formed from interbedded grey muds and silts. The fauna, which are quite abundant in the younger beds, include brachiopods, pelecypods, bryozoans, crinoids, and during present investigation acritarchs have also been consistently recorded, all of these were probably well suited to shallow water depth and accompanying fine-grained bottom sediments.

During the formation of the Chadakoin, there was a gradual increase in the proportion of sands to muds, marking the westward migration of the Devonian shoreline. Sponges are found locally and seem best suited to sandy bottoms. Pelecypods are also fairly common in some places.

As the Cattaraugus formed deposition of coarse sands and small pebbles became more frequent. Pebbles were transported by swift moving streams and may have been further distributed by near-shore currents. Marine fossils are present, especially pelecypods. Land plants were carried into the sea by rivers.

SEDIMENTARY STRUCTURES

A great variety of sedimentary structures may be observed in the area investigated. A short description of some of the common

features is given below:

The concretions and septaria of various shapes and sizes are found in the Dunkirk, South Wales and Gowanda. They vary in composition. Most of these are calcareous while others are arenaceous.

In some of the thin limestone beds in Northeast Shale, close to New York--Pennsylvania line, some cone in cone structures have been recorded. These structures are the result of solution which occurs under pressure.

Siltstone and sandstone beds sometimes contain wave or current ripple marks and their under surfaces may show groove casts. The sandstones and conglomerates of the Cattaraugus often exhibit fine examples of cross bedding, characteristic of shallow water deposits.

Some of the conglomerate contains cut-and-fill structures resulting from local erosion prior to deposition of the conglomerate.

PREVIOUS RESEARCH ON STRATIGRAPHY AND PALAEONTOLOGY OF THE AREA INVESTIGATED

Text fig. 1-3 presents a list of most of the geologist (stratigraphers) who have contributed to the knowledge of the Upper Devonian stratigraphy of New York State and Pennsylvania, U.S.A. Several of these works are sufficiently comprehensive to deserve special mention. Hall (1839) was the first who laid the foundation and subsequently (1840-1843) presented important contributions to our knowledge of Western New York State stratigraphy and palaeontology. Although his work is over one hundred years ago and has considerably been modified in terms of stratigraphic and paleontologic nomenclature, however, it is still basic and fundamental. Pertinent informations on stratigraphy and palaeontology have been gathered

by detailed works of William (1887), and Glenn (1903) and Butts (1908). These workers drew geologic maps of the Salamanca and Olean regions. Butts (1908) studied the stratigraphy of Pennsylvania, U.S.A. Chadwick (1919, 1923, 1924, 1933, 1935) and Caster (1934) also provided valuable data publishing articles concerning the stratigraphy and palaeontology of New York and Pennsylvania, U.S.A. Data have also been gathered by the works of Pepper & de Witt (1951) who investigated the Dunkirk, South Wales and Gowanda and these workers enlarged on previous geologists' informations. Hall (1959) studied some brachiopods in the area. Muller (1963, 1964, 1965) provided some informations on quaternary geology of New York, U.S.A. Richard (1964, 1975), Richard & Fisher (1970) drew useful maps of the area.

Tesmer gathered pertinent informations on stratigraphy and palaeontology from hundreds of exposures scattered throughout Western New York, including Erie, Chautauqua and Cattaraugus counties, publishing many articles since 1954.

Finally, the chapter will not be completed unless tribute is paid to Dr. John B. Richardson who provided fresh and complete unpublished informations and through his courtesy the writer was able to analyse precious material of the area.

CHAPTER 2

PREVIOUS PALYNOLOGICAL INVESTIGATIONS

PREVIOUS PALYNOLOGICAL INVESTIGATIONS IN THE UPPER DEVONIAN STRATA

Most of the early investigations in palynology were concerned with Pleistocene or post-Pleistocene sediments. Probably the first person to record fossil spores in the Upper Devonian of the U.S.A. was Arnold (1933). Arnold observed miospores, including some similar to the genus Hystricosporites McGregor, from the Pocono Sandstone near Port Allegany, McKean County, Pennsylvania. He recorded spore populations having a size ranging from 35-150μm. The forms falling into the upper limit were regarded as megaspores by Arnold. On the basis of some Sigillarian genera, Arnold (loc. cit.) compared Pocono material with the Upper Devonian sediments of the Donetz Basin, South Russia.

In the mid nineteen thirties Arnold (1936) again observed anchor-spined miospores from the Upper Devonian rocks of Scaumenac Bay, Canada and Pittston, Pennsylvania, U.S.A.

In the early nineteen forties Luber and Waltz (1941) published a detailed account of microspores and pollens from the Palaeozoic rocks of the U.S.S.R. In this paper the authors dealt with coal facies ranging from Cambrian to Carboniferous in age.

Naumova's (1953) work is regarded as one of the major creative contributions to the study of Devonian palynology. In 1957a Kedo recorded 'Hymenozonotriletes lepidophytus' and subsequently (1957b, 1962, 1963) published on stratigraphical palynology of the Pripyat Depression in Bielorussia S.S.R.

Chaloner (1959) presented an important contribution to our knowledge of Canadian Upper Devonian megaspores. The lithology of the material he investigated was coal and shale belonging to the

Ockse Bay, on the south-west coast of Ellesmere Island, Arctic Canada. Six new species including two new genera were erected. In addition to variously sculptured plant macrofossil components, Chaloner recorded a spore having anchor-spined processes. It is of interest to note that a spore possessing similar spine structures had long been observed from Middle Old Red Sandstone of Scoltand. However, Lang's (1925) type G is much smaller than those of Chaloner's specimens. Chaloner discussed briefly the origin of the spore, made a comparison with other megaspore assemblages and finally concluded that there is a gradual decrease in the mean size of the megaspores from the Carboniferous through Cretaceous, whereas the spores increase in size from the Devonian to the Carboniferous.

In the United States Winslow (1962) published on spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio. In 1963, Guennel reported a Middle to Upper Devonian mioflora from the fissure-filling in a Middle Silurian reef of Illinois. This assemblage was dominated by cingulate miospore genera. Later on, from New Albany Shale, Kentucky, Bharadwaj et al. (1971) recorded Upper Devonian plant spores as well as microfossils of algal and animal origin. Wary & Traverse (1973) illustrated and commented briefly upon some miospores present in shale and 'coals' of a Devonian-Mississippian transition zone, Central Pennsylvania.

The Upper Devonian of Australia received attention during the early nineteen sixties, with the publications by Balme (1962) and Balme & Hassell (1962). In 1968 Evans published a brief paper discussing the Upper Devonian and Lower Carboniferous miospores of the Mulga Down Beds, New South Wales. He interpreted that his first assemblage had a close similarity with the Famennian microfloras in the Fairfield Formation of the Fitzroy Trough, Canning Basin recorded by Balme & Hassell (1962).

Wray (1964) stated that Vallatisporites was restricted to the Carboniferous in western Libya. He also commented on a species of Leiozonotriletes with a reticulate sac which he considered to be useful in determining the Devonian-Carboniferous boundary. From Wray's illustration, pl. 1, fig. 25, this species appears to be R. lepidophyta.

McGregor & Owens (1966), Owens (1971) and McGregor (in McGregor & Uyeno (1972) investigated the Devonian palynology of the Canadian Arctic.

Streel (1966) and Paproth & Streel (1970) analysed samples from the Upper Devonian-Lower Carboniferous section in type localities of Belgium and Germany. Bouchaert et al. (1969) working on the type sections in the Dinant Basin of Belgium made an attempt to publish a biostratigraphical chart for the Upper Devonian (upper most Frasnian-Fammennian and Lower Tournaisian, F3-Tn1). Almost fourteen zonal complexes were established in this stratigraphical interval. Streel's miospore zones (florizones) were based on the relative abundance of various miospores, most of which were small, simply sculptured and long ranging. At the top of the Frasnian he observed almost laevigate and simply ornamented forms where as in Fammenian pseudosaccate, both smooth and sculptured species were frequently encountered. In Fa2d above the Evieux Beds Streel observed the first appearance of Retispora lepidophyta (Kedo) Playford and Vallatisporites pusillites (Kedo) Dolby & Neves. Towards the top of the Famennian R. lepidophyta was gradually replaced by its two varieties, var. tenor and var. minor. This gradual replacement

A: System or subsystem; B: Stage; C: Subdivision of stage; D: Spore "florizone".

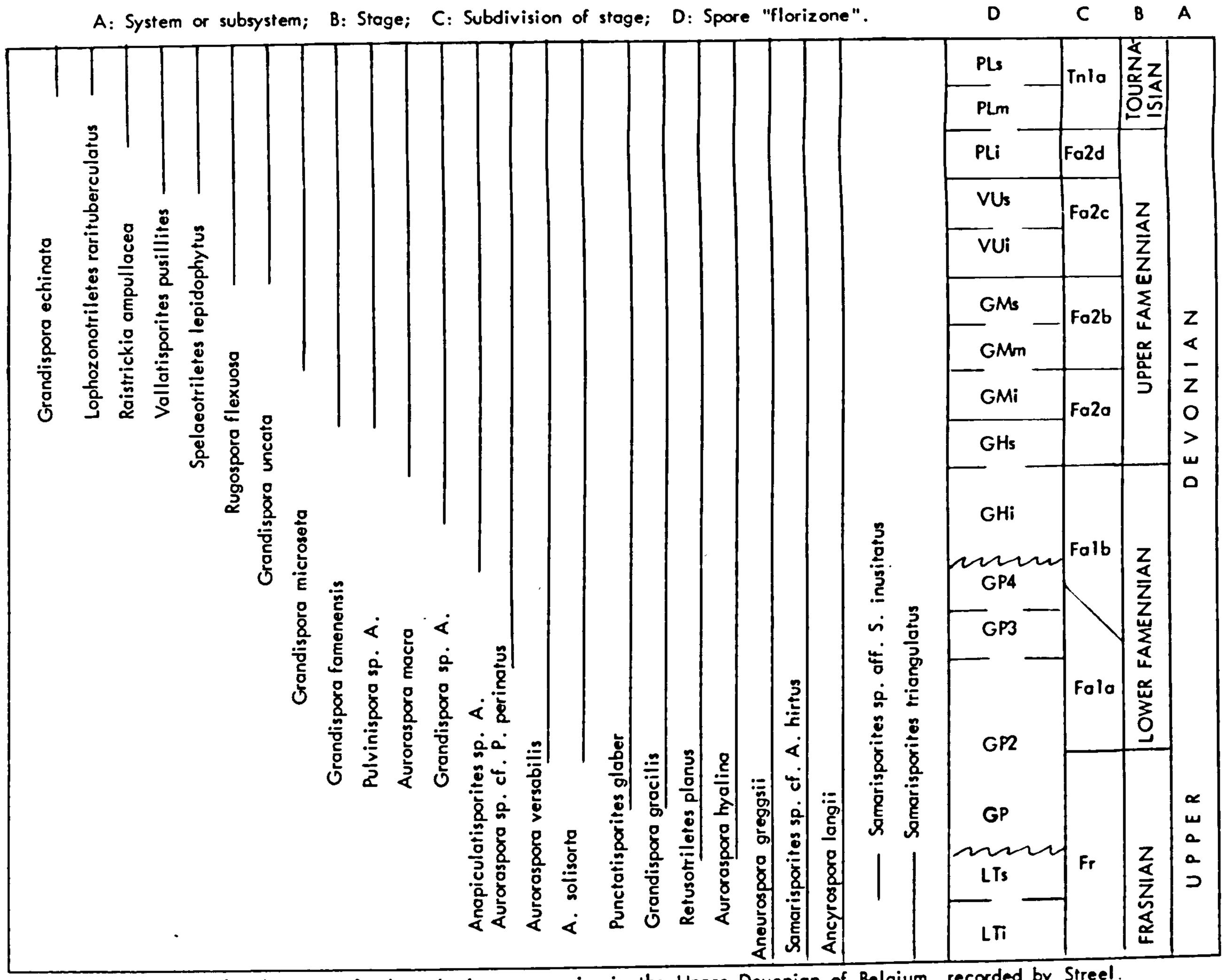


Table 2.1. Stratigraphical ranges of selected miospore species in the Upper Devonian of Belgium, recorded by Streel.

was attributed to an evolutionary trend rather than the effects of facies variation. It is noteworthy that the case was different in Bielorusian S.S.R. where changes were more abrupt between the Lower Lebedian and Upper Lebedian-Dankov Formation. Since Kedo did not publish range charts her subdivision is speculative.

Streel (1966) established five zones (B-F) based on biometric distinction within the forms of species R. lepidophyta. This biometrically recognizable changes were also observed outside the Ardenno-Rhenans Basin, the areas where these were first identified.

Recently, Streel in Becker et al. 1974 produced a complete and improved biostratigraphic chart for the Upper Devonian and basal Dinantian of Belgium. Sixteen miospore zones were recognized but on the basis of first appearance of different species he divided them into nineteen subzones. Important miospore forms that make their first occurrence at different stratigraphic levels are shown in Table 2.I.

C.I.M.P. meeting in 1969 at Sheffield was mainly devoted to palynology of the Devonian/Carboniferous boundary. Many palynologists throughout the world contributed to this meeting and a total of nine papers containing the miospore assemblages and stratigraphical informations of this horizon were published in 1970. Bouckaert, Streel & Thorez described in detail different Famennian-Viséan type sections in the Ourthe Valley in the North East part of Synclinorium of Dinant basin (Belgium) and correlated on palaeontological evidence . They also made an attempt to correlate these Devonian-Carboniferous transition beds with the classic localities of Comblain-au-Pont Rivage-garc (Belgium), Etroeungt (Avesnois, North of France) and the "Hangenberg Schiefer" (Hönnetal). Combaz &

Streel systematically described miospores and acritarchs which indicated that core samples studied from Pas-de-Calais were of a lower Tournaisian age. A comparison with Dinant basin was also made by these authors. Streel gave an account of stratigraphical and geographical distribution of 'Hymenozonotriletes lepidophytus' and 'H. pusillites'. Paproth & Streel described miospore assemblages from the Upper Devonian-Lower Carboniferous sections in the type areas of Belgium (Ardennes) and Germany (Rhenish Schiefergebirge). Owens & Streel amply documented previous work and literature published on the palynology of the Devonian-Carboniferous boundary and analysed the stratigraphical significance of many of taxa that occur in this part of the column e.g. Retispora lepidophyta (Kedo) Playford, Vallatisporites pusillites (Kedo) Dolby & Kedo. Dolby described the miospore assemblages of different sections from Devonian-Carboniferous transition measures in south-west England (Baggy Point, Burlington Combe, West Angle Bay) and southern Ireland (Hook Head). Utting & Neves published on the palynology of the Lower Limestone Shale Group and Portishead Beds of the Avon Gorge, Bristol, England. McGregor briefly documented the association of 'Hymenozonotriletes lepidophytus' Kedo in different miospore assemblages recovered from widely separated parts of Canada. The areas he studied were Ontario, Nova Scotia, and Yukon Territory. Finally von Almen reported on the micro-floral assemblages from the Woodford Shale, Oklahoma U.S.A. In the Woodford Shale, which spans the Devonian-Carboniferous boundary, von Almen could not record 'Hymenozonotriletes lepidophytus' Kedo and therefore it was suggested that this part of Woodford Shale Formation is younger than Strunian.

Chibricova (1973) discussed the floral assemblages of the Devonian-Carboniferous boundary in describing the age of the Solonchatka Creek. The latter is in the basin of the Suunduk River, a left tributary of the Ural River. This palaeontologically barren strata had only one site rich in flora which was analysed by two Russian workers and found to be an early Carboniferous (Etroeurgtian) in age. Later on, one of these workers changed his original opinion and dated the Solonchatka flora as early Famennian. Chirbricova (loc. cit.) investigated the strata palynologically and re-established an early Carboniferous age for these rocks.

In recent years enormous palynological data on Upper Devonian sediments have been documented from different parts of the world. Dolby (unpublished thesis, 1970) investigated the palynology of the Devonian-Carboniferous transition measures in south-west Britain and southern Ireland. Allen (in Gayer et al. 1973) briefly discussed the palynology of the Old Red Sandstone from the Taff Gorge road sections (South Wales).

Clayton et al. (1974) published a brief description of miospore assemblages from the Cork Beds of southern Ireland. The authors emended the Upper Devonian-Lower Carboniferous miospore zonation schemes previously proposed by Streel (1966, 1969) and Paproth and Streel (1970) from Belgium and by Neves et al. (1972) from the British Isles. Streel named his 'florzones' by the first occurrence of Vallatisporites pusillites and Retispora lepidophyta (PL) in the Upper Devonian assemblages while Dictyotriletes trivatis and Hymenozonotriletes explanatus (TE) in miospore assemblages recorded from Lower Carboniferous. On the other hand Neves et al. (loc. cit.) also observed the first appearance of V. pusillites and R. lepidophyta in the Upper Devonian sediments and the assemblages was referred to as (PL) while in the miospore assemblages from the

STREEL 1966	NEVES ET AL. 1972	CLAYTON ET AL. 1974	
D.trivialis - H.explanatus (TE) Zone	V.nitidus - V.vallatus (NV) Zone	V.nitidus - V.vallatus (NV) Zone	V. vallatus - R. incohatus (VI) Subzone
			H. lepidophytus - V. nitidus (LN) Subzone
V.pusillites - H.lepidophytus (PL) Zone	V.pusillites H.lepidophytus (PL) Zone	V.pusillites H.lepidophytus (PL) Zone	

Table 2.2. Comparative study of miospore zonation schemes in the Upper Devonian - Lower Carboniferous assemblages established by Streel (1966), Neves et al. (1972) and Clayton et al. (1974).

Lower Carboniferous rocks they observed Verrucosisporites nitidus in the association of V. vallatus, consequently the miospore zone was named (NV).

Clayton et al. (loc. cit.) established a transitional assemblage between the PL and NV zones of Neves et al. (loc. cit.) since it contained diagnostic elements of both miospore complexes. Two subzones were included within the NV zone, the LN and VI subzones. The former subzone was characterized by the first appearance of Verrucosisporites nitidus (Naumova) Playford and Lophozonotriletes malevkensis Naumova in Kedo 1963, whereas the base of VI subzone was indentified by the disappearance of Vallatisporites pusillites and Retispora lepidophyta (see table 2.2.).

Higgs (1975) reported Devonian-Carboniferous miospore assemblages from Hook Head, southern Ireland.

Turnau's (1975) paper incorporated results of palynological investigations of northern Polish Famennian-Tournaisian deposits.

Massa and Moreau-Benoit (1976) published a succint paper containing the Devonian palynological results from the Rhadames Basin, western Libya.

Playford (1976) gave an overall picture, as comprehensive as sampling permitted, of the palynological sequence in the Upper Devonian-Lower Carboniferous strata of western Australia.

A recent paper by Chi & Hills (1976) dealt chiefly with the description of both mega- and miospore species and included some stratigraphical findings, the samples investigated were collected from the Devonian (Givetian - Lower Famennian) deposits of Arctic Canada.

CHAPTER 3

TECHNIQUES

SAMPLE PREPARATION TECHNIQUES AND METHOD OF STUDY

The techniques used in sample preparation are those in common usage in Palaeozoic palynology and are summarised in Table 3.I. Precautions were taken at all stages to avoid contamination.

Single Grain Mount.

In this technique, a drop of wet residue was mixed with an equal volume of melted glycerine jelly on a slide at approximately 40°C. The slide was maintained at this temperature until most of the water had evaporated, and was then allowed to cool. Selected specimens were picked from the open glycerine mount using the tip of a fine needle, and were transferred to a drop of melted glycerine jelly on a clean slide. The clean slide was heated to 40°C and a small circular cover slip emplaced. The mount was sealed with beeswax to prevent dessication of the glycerine jelly.

Scanning Electron Microscope Mounts.

In this process, the residue was thoroughly mixed with water and spread on a microscope slide. The slide was then dried on a hot plate at 60°C. Well preserved specimens were picked using a fine bristle with a drop of absolute alcohol and were mounted on a scanning electron microscope (SEM) stub.

During the present investigation it was found that the best results were obtained when miospores were mounted on a small circular cover slip (10 mm in diameter) glued to the top of a standard aluminium specimen stub. This method produced a better quality background (see plate 7, fig. 13; plate 9, fig. 2) than when the miospores were mounted directly onto the stub, as the uneven surface of the stub appeared very rough at high magnification (see plate 18, fig. 6; plate 19, figs. 1-3).

1. Sample washed and crushed to 1mm. particles.

2. Tested for carbonate with dil. Hcl., if positive, treated with dil. Hcl. until all carbonate removed.

3. Removal of silicates. Sample placed in polythene pot, 40% HF added carefully. Heated on sandbath 1-4 days. Stir occasionally. Wash well by repeatedly decanting liquid and adding distilled water.

4. Sample examined under microscope.

5. Residual mineral matter removed by heavy liquid separation, using zinc bromide.

6. Placed in porosity 4 sintered funnel. Thoroughly washed.

7. Optional oxidation with Conc. HNO3.

8. Optional ultrasonic vibration to disaggregate clumps of residue. Few drops of dispersal agent e.g. cellusize added before drying on cover-slip.

9. Cover-slip mounted on 3x1 slide using Canada Balsm.

10. Microscope examination.

Table 3.I. Summary of laboratory procedure for extracting and mounting spores from argillaceous rocks.

To prepare for SEM photography the stubs and mounted miospores were coated in a vacuum evaporator with a very thin layer of metal or carbon. Carbon, silver and gold/palladium alloy were tested as coating media. The best results were obtained using carbon, consequently this medium was used for all the SEM work on the miospores.

Muir (1970) has given a comprehensive summary of the principles and application of electron microscopy and also she has discussed the various mounting techniques. For quick re-examination of the specimens following the completion of electron microscope photography, a technique suggested by Laing (1974) was found to be advantageous. A grid was glued to the stub where a number of specimens could then be mounted separately on the same stub.

Counting.

During the course of present investigation the writer was not settled on a count of particular entities, rather a total count of 200-500 palynomorphs was undertaken in order to determine a complete qualitative as well as quantitative estimation of an assemblage. Samples yielding more species were given larger count than those yielding a few species.

Slides were usually examined under magnification of X400 and XI000. Examination of entire slides were carried out under magnification of X400, counting and initial identification were done under XI000, using an oil immersion objective. At least three slides were then examined for species.

Method of Study.

The slides containing holotypes and figured specimens are housed in the Palynology Laboratory, Department of Geology, King's College, University of London. The stage coordinates were obtained on NIKON microscope No. 84368 of the above Department. The slides have been examined with their labels at the left of the examiner and 'N-S' coordinates were noted first. The reference numbers of specimens illustrated from strew mounts are given as the section and sample number followed by the slide number and finally the vernier readings. For example, NY96A 78 I22832I refers to slide no. 78 of sample no. NY96A (the Bush Hill Section) and stage coordinates I228 by 32I.

Scanning electron microscope mounts are also individually numbered and denoted by the prefix 'SEM'.

CHAPTER 4

MORPHOGRAPHICAL TERMINOLOGY

MORPHOGRAPHICAL TERMINOLOGY

Numerous independent workers have produced a proliferation of terms and 'jargon' in palynology. The morphographical terminology used here is essentially that suggested by Grebe 1971. The technical terms found necessary in the present work are explained and illustrated in text fig. 4.1- 5 which are modified from Grebe 1971. General features and variations in equatorial and longitudinal views are illustrated in text fig. 4.1; different shapes in text fig. 4.2; tetrad mark and associated features in text fig. 4.3; structural features and exine organization in text fig. 4.4; and sculptural elements in text fig. 4.5.

In the compilation of this Chapter extensive use has been made of the work of Dettmann (1963), Richardson (1965), Neves & Owens (1966), Smith & Butterworth (1967) and Grebe (1971).

Terms used during the course of present investigation are defined below.

SHORT GLOSSARY OF TERMS

TERMS USED IN ORENTATION, DESCRIPTION AND SHAPE

AMB The shape of the equatorial outline of a spore viewed from polar axis. The amb is normally of three shapes: circular, triangular or ellipsoid (fig. 3).
Other kind of shapes are illustrated in text fig. 4.2.

EXINE The cutinized part of the spore coat.

INTEXINE Inner layer of a spore exine (inner body).

EXOEXINE Outer layer of a spore exine that can bear structural and/or sculptural elements.

GENERAL TERMS USED IN ORIENTATION AND DESCRIPTION

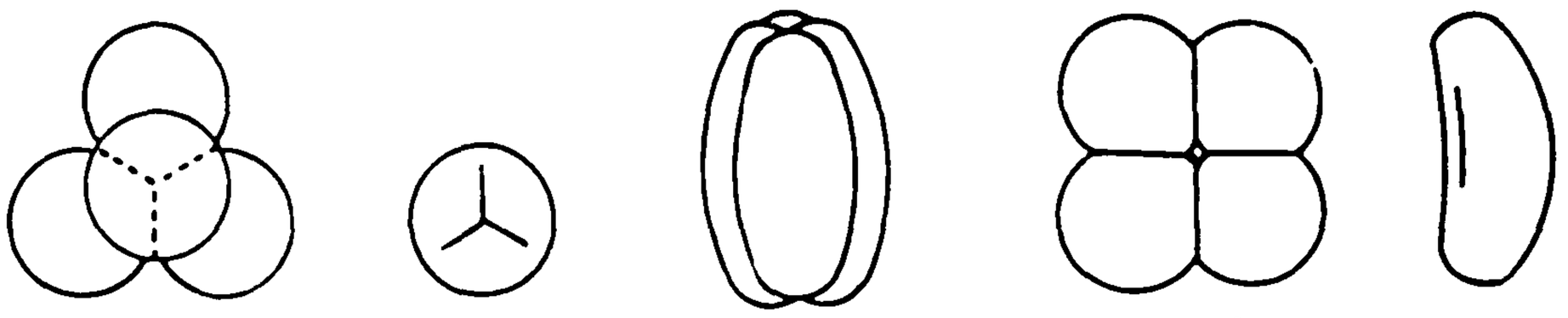


FIG 1 TETRADS

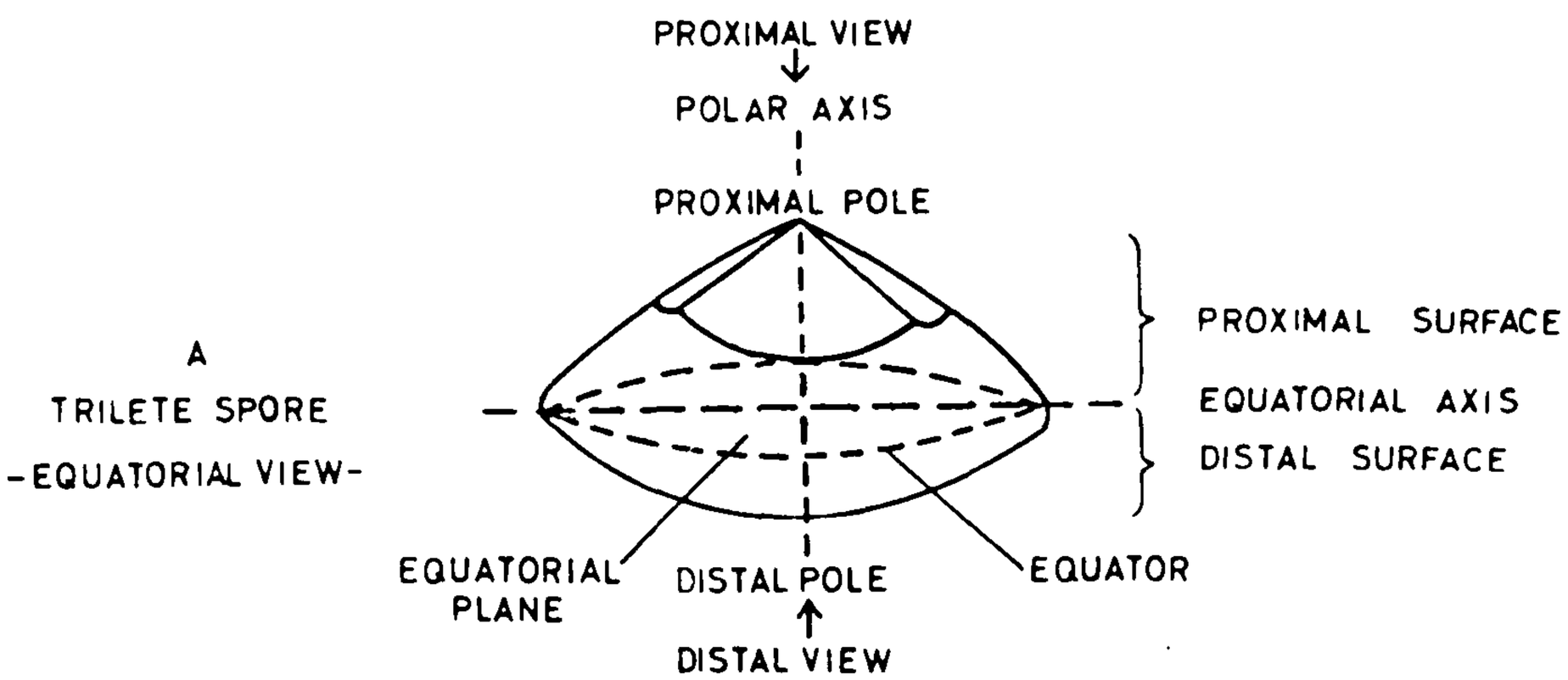


FIG.2

TEXT FIG. 4 — 1

TETRAD Unit of four spores formed by one mother cell (figs. 1A-B).

TETRAHEDRAL TETRAD Common type of tetrad, spores arranged in a tetrahedron (Fig. 1A). Spores from this tetrad are normally trilete.

TETRAGONAL TETRAD Spores arranged in one plane (fig. 1B). Spores from this tetrad are commonly monolete.

EQUATOR The region where proximal and distal surfaces meet (figs. 2A-B).

PROXIMAL SURFACE The spore hemisphere that was turned inward in the tetrad and which usually bears a tetrad mark (figs. 2A-B).

PROXIMAL POLE The geometrical centre of spore and point of origin of trilete mark in trilete spore (fig. 2A), and mid-point of monolete mark in case of monolete spore (fig. 2B).

DISTAL SURFACE The spore hemisphere that was turned outward in the tetrad and is therefore opposite the tetrad mark (figs. 2A-B).

DISTAL POLE The point opposite the proximal pole (figs. 2A-B).

POLAR AXIS Axis joining the proximal and distal poles (figs. 2A-B).

EQUATORIAL AXIS Any axis in the equatorial plane which intersects the polar axis (figs. 2A-B).

RADIAL REGION The area in the immediate vicinity of tetrad mark and the corresponding portion of distal surface (fig. 2C).

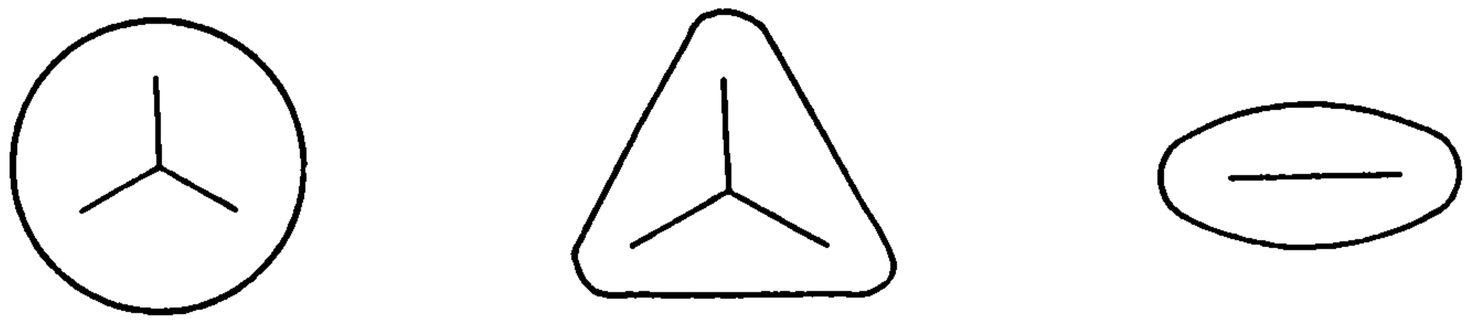
INTERRADIAL REGION The area between adjacent laesurae in trilete spores, and the corresponding portion of the distal surface (fig. 2C).

TRILETE Possessing a triradiate tetrad mark (fig. 2C).

MONOLETE Possessing an unbranched tetrad mark (not observed during the present study).

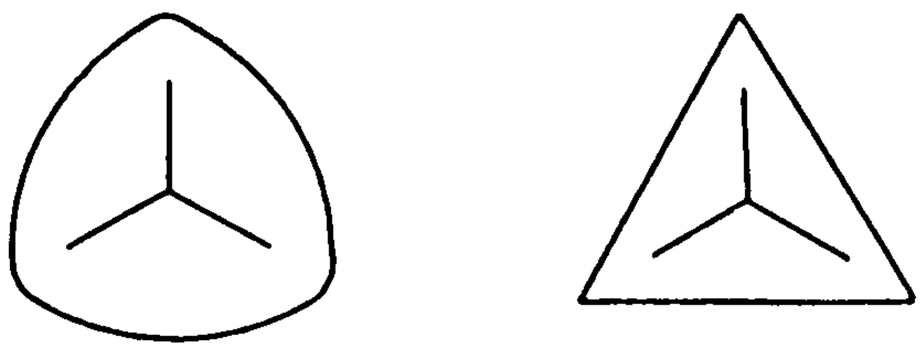
PROXIMAL PROFILE The shape of the outline of proximal surface as seen in equatorial view, the basic profiles are: flat, convex, pointed or concave (fig. 6).

SHAPE



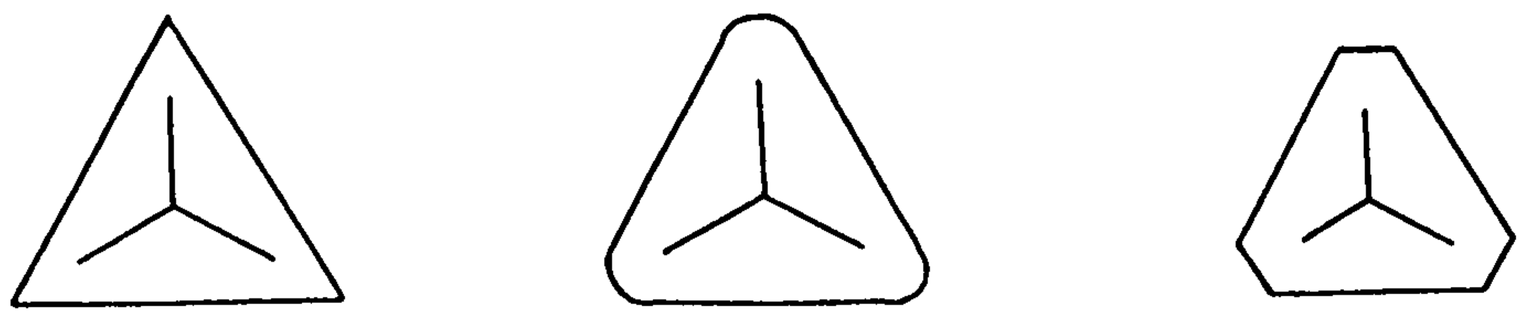
CIRCULAR TRIANGULAR ELLIPSOID

FIG 3 SEEN IN POLAR VIEW (AMB)



CONVEX STRAIGHT

FIG 4 SIDES SEEN IN POLAR VIEW



ANGULAR ROUNDED TRUNCATE

FIG 5 ANGLES SEEN IN POLAR VIEW

SHAPE IN EQUATORIAL VIEW

FLAT CONVEX POINTED

FIG. 6 PROXIMAL PROFILE

FLAT CONVEX POINTED

FIG 7 DISTAL PROFILE

TEXT FIG 4 — 2

DISTAL PROFILE The shape of the outline of the distal surface as seen in equatorial view, the basic profiles are: convex, pointed, flat (fig. 7).

TERMS USED IN DESCRIBING THE TETRAD MARK AND ASSOCIATED FEATURES

TETRAD MARK The mark(s) separating contact areas. Bilaterally symmetrical spores possess a single (monolete) mark: those with radial symmetry possess three marks (trilete) radiating from the proximal pole.

TRILETE MARK Three laesurae radiating from their point of origin at the proximal pole (figs. 8-9).

MONOLETE MARK Consists of a single laesura (fig. 8).

LAESURA The suture of a trilete or monolete mark, which may be simple or when accompanied by modifications of the adjacent exine, termed labrate.

LIP Thickened or folded modification of exine bordering the suture, also called labrum (fig. 9).

CONTACT AREA That part of proximal face in contact with a similar face of another spore in the tetrad. A trilete spore has three contact areas meeting at the proximal pole. Each contact area is bounded laterally by two laesurae of the tetrad mark and sometimes clearly delimited in its outer part by a more or less curved line the curvatura (fig. 8A).

CURVATURA The outer limit of contact area (fig. 8A). This may be defined by a line of thickening or change in exine thickness or in sculpture, if reduced called c. imperfecta (fig. 8B), if continuous called c. perfecta (fig. 8A).

GULA A marked extension of the labra and in some cases parts of the contact areas at the proximal pole (fig. 10).

APICAL PAPILLA Dark spot or prominence close to the proximal pole in the interradial region.

TETRAD MARK AND ASSOCIATED FEATURES

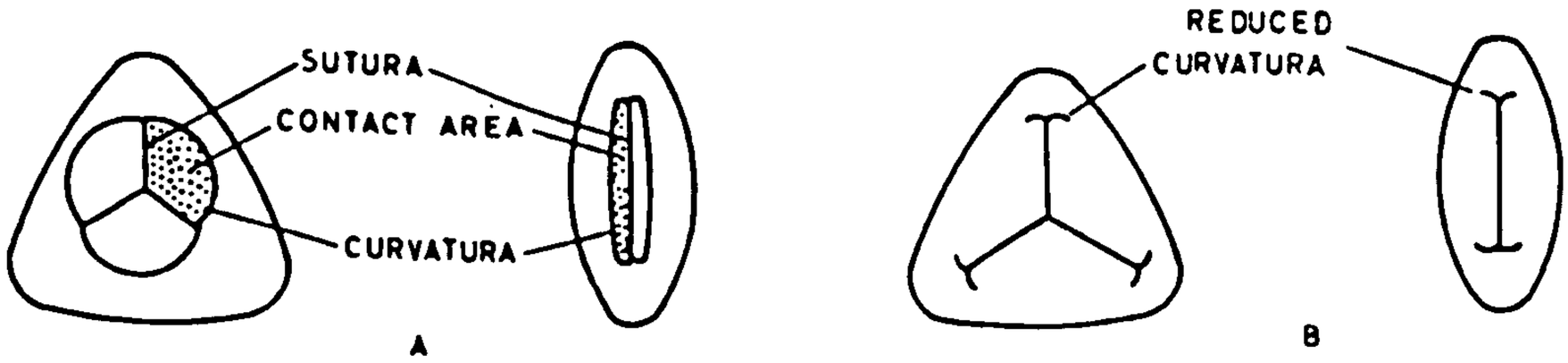


FIG. 8

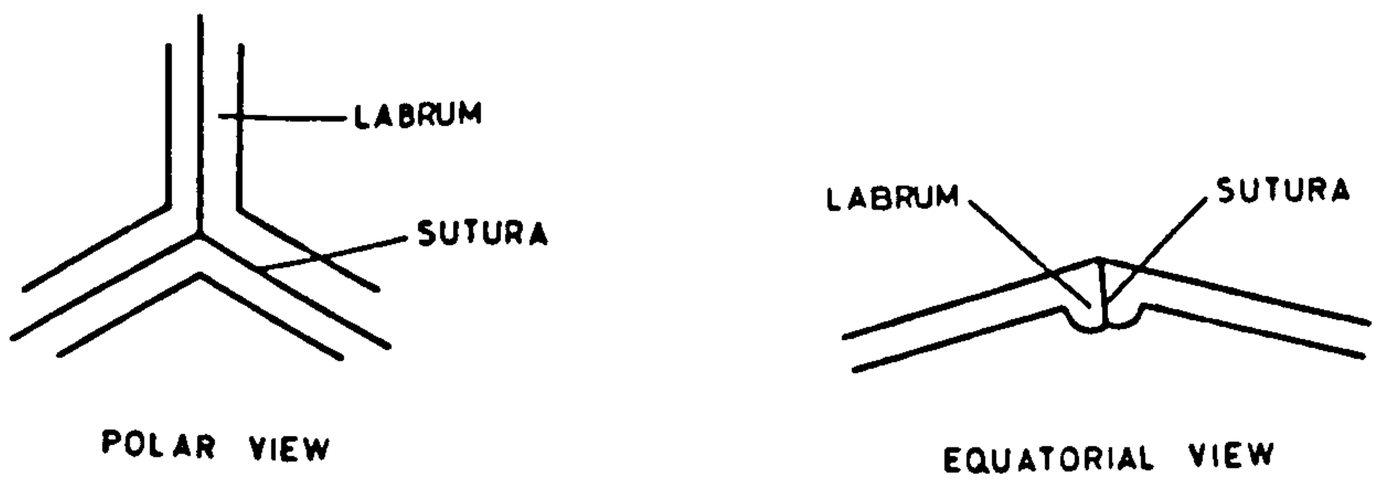


FIG. 9

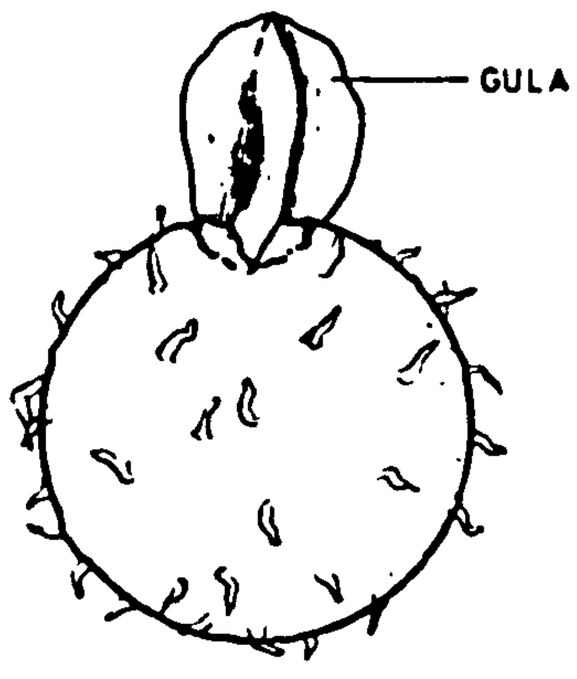


FIG. 10

TEXT FIG. 4 — 3

TERMS USED IN DESCRIBING STRUCTURAL FEATURES

CAVUM (General structural features) any cavity due to the separation of two exine layers - hence cavate spores (in contrast to acavate).

CAMERA (Innovated by Neves & Owens 1966 to replace 'cavate', but not used in the present study). Space formed by separation of exine layers, unaccompanied by collumellate infra-structure hence camerate.

CAVATE (Dettman 1963, p. 18) asaccate spores in which the wall layers are partially or almost completely separated from each other by a cavity. Outer layer may be well separated from inner layer to form a pseudosaccus.

PSEUDOSACCUS A cavity of trilete cavate spores formed by the separation and extension of the exoexine away from the intexine either equatorially or to a greater or lesser extent proximally, and/or distally - hence pseudosaccate miospores (fig. 15).

SECONDARY FOLD Folds produced by compression subsequent to miospore burial in sediments.

LIMBUS A narrow, equatorial zone in certain pseudosaccate miospores (monosaccate spore sensu Potonie & Kremp), formed by the fusion of the proximal and distal exoexine layers (fig. 16).

EQUATORIAL CRASSITUDE A more or less regular thickening of the equatorial region which is usually rounded in cross section (fig. 11).

DISTAL CRASSITUDE Thickening or thickenings of the exine of the distal surface (fig. 18).

PATINA (Butterworth and William 1958, p. 381). Crassitude covering entire distal surface.

CINGULUM A more or less regular thickening of the equatorial to subequatorial region which is usually wedge-shaped in cross section, (fig. 12), hence cingulate miospores.

STRUCTURAL FEATURES

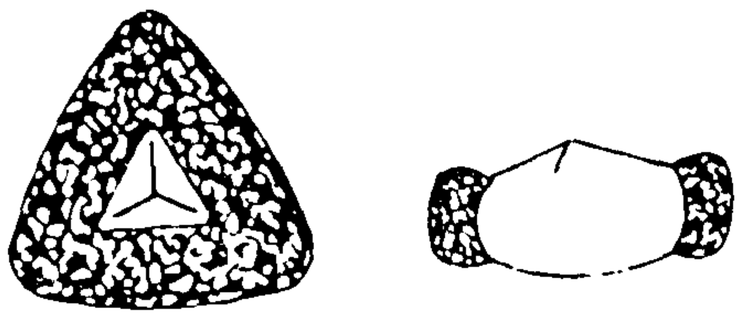


FIG 11 EQUATORIAL CRASSITUDE

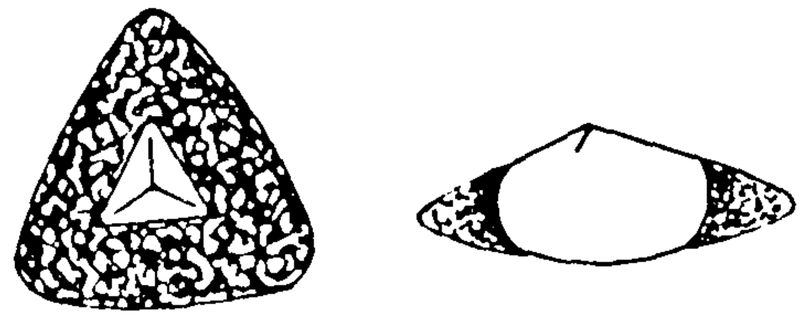


FIG 12 CINGULUM

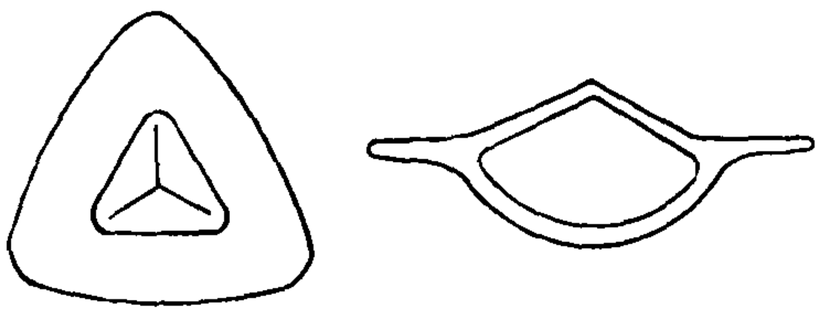


FIG 13 ZONA

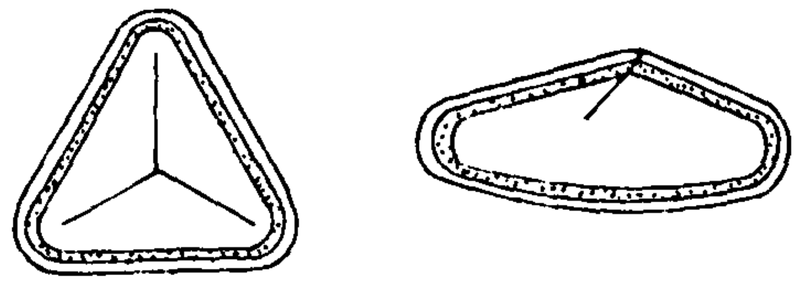


FIG 14 AZONATE

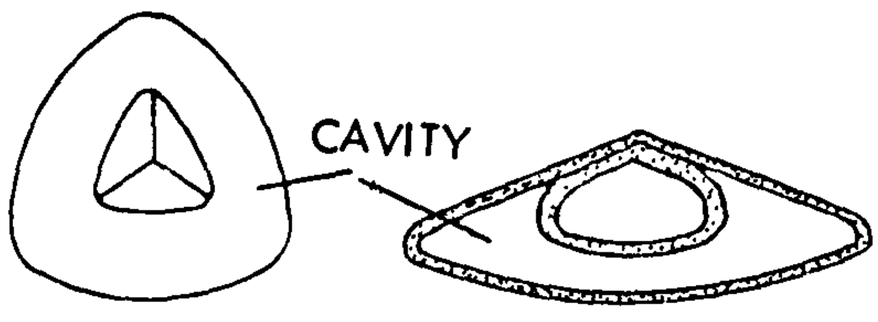


FIG 15 PSEUDOSACCATE

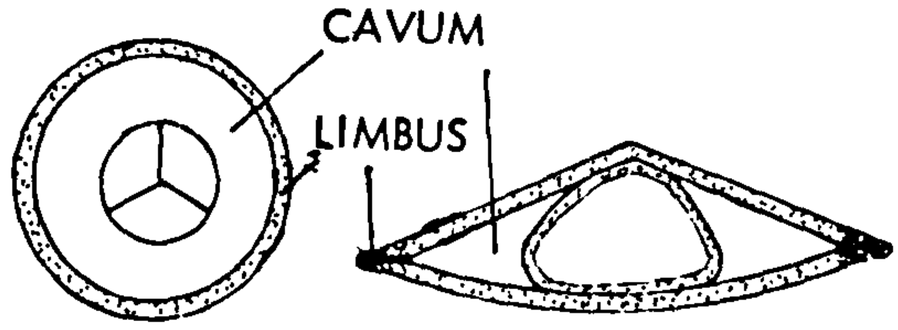


FIG 16 MONOPSEUDOSACCATE SPORE WITH LIMBUS

FIG 17 VACUOLES

FIG 18 DISTAL CRASSITUDE

TEXT FIG. 4— 4

ZONA An equatorial to proximally-subequatorial membranous extension of the exine (fig. 13), hence zonate spores.

Miospores without this feature may be referred to as azonate (fig. 14).

VACUOLES Rounded to elongated spaces within an equatorial feature (fig. 17).

ORNAMENTATION WITHOUT SCULPTURE

LAEVIGATE Exine smooth or homogeneous.

SCABRATE Exine flecked with minute pits or elevations less than 1µm in greatest dimension giving it a rough appearance.

(PUNCTATE Exine with minute depressions).

INFRASTRUCTURE Any ornamentation due to small sculptural elements inside of the exine.

TERMS USED IN DESCRIBING THE EXTERNAL ORNAMENTATION OF THE EXINE (SCULPTURE)

Sculptural elements and patterns can be divided into two main groups:

a) Apiculate elements and pattern:

Those based on projections from the general surface.

b) Murornate elements and patterns:

Those based on elevation of the general surface.

APICULATE ELEMENTS AND PATTERNS - NON POINTED TERMINATIONS

VERRUCAE Projections whose height is less or equal to greatest diameter. Base of the element subcircular to irregular, top rounded to slightly flattened, never pointed (fig. 19).

VERRUCATE SCULPTURE A sculptural pattern formed by verrucae.

GRANA Elevations whose height is - as in verrucae - less than or equal to the greatest diameter.

The grana can be distinguished from the verrucae by their more or less regular outline and also by their smaller size (fig. 20).

GRANULATE SCULPTURE A sculptural pattern formed by grana.

TUBERCULA Projections whose height is greater than the greatest diameter. They are rounded at the top and may be slightly constricted at the base. They are distinguished from the pila by the far less distinct constriction at the base and from the verrucae by the different ratio from greatest diameter to height (fig. 21).

TUBECULATE SCULPTURE A sculptural pattern formed mainly by tubercula.

PILA Projections consisting essentially of a more or less spherical head carried on a thin neck or stalk (fig. 22).

PILATE SCULPTURE A sculptural pattern formed by pila.

BACULA Projections in which the height is greater than the basal diameter; bases more or less rounded in surface view; sides parallel, or slightly converging; apices flat or partate (fig. 23).

BACULATE SCULPTURE A sculptural pattern formed by bacula.

POINTED TERMINATIONS

CONI Projections in which the height generally equals, or exceeds, the basal diameter, but less than twice that diameter; bases almost circular in surface view, top pointed (fig. 24).

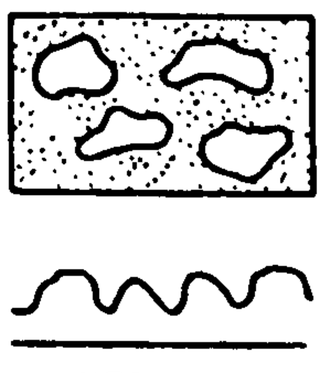
CONATE SCULPTURE A sculptural pattern formed by coni.

SPINAE Projections in which the height is at least almost circular in surface view, apices pointed (fig. 25).

SPINATE SCULPTURE A sculptural pattern formed by spinae.

SCULPTURE ELEMENTS AND PATTERNS

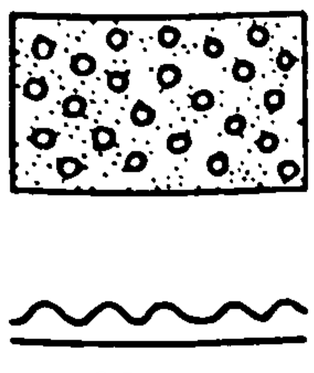
APICULATE SCULPTURE ELEMENTS WITH NON-POINTED TERMINATIONS



VERRUCAE

h ≤ d

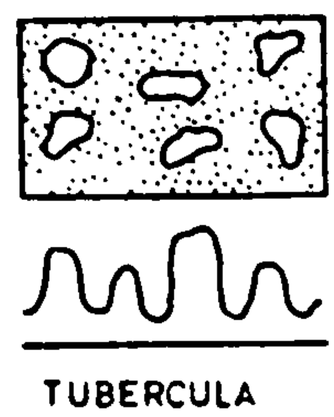
FIG. 19



GRANA

h ≤ d

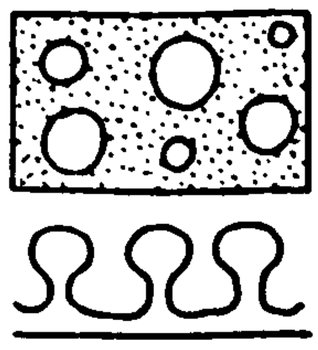
FIG.20



TUBERCULA

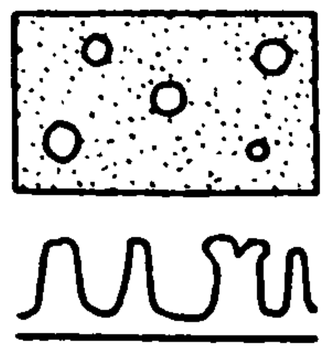
h > d

FIG.21



PILA

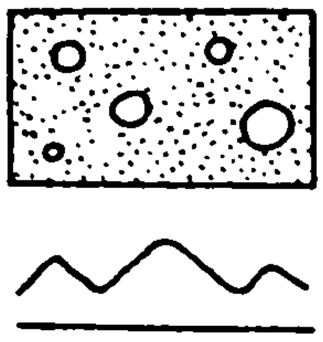
FIG. 22



BACULA h > d

FIG.23

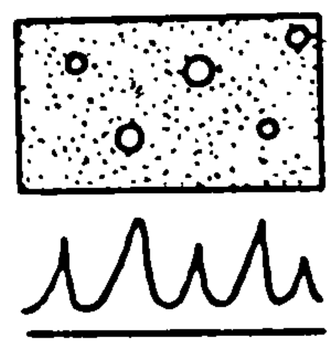
APICULATE SCULPTURE ELEMENTS WITH POINTED TERMINATIONS



CONI

h < 2d

FIG. 24

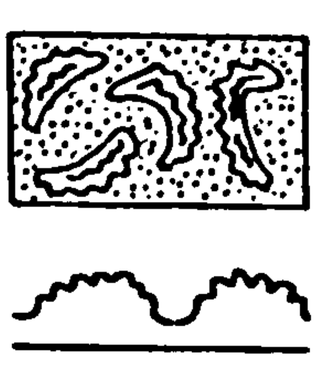


SPINAE

h ≥ 2d

FIG. 25

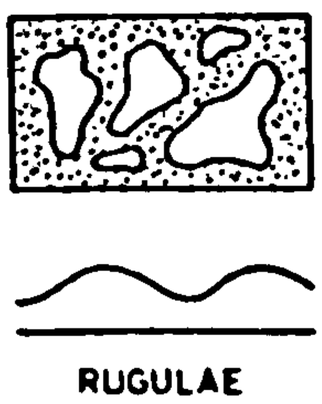
MURORNATE SCULPTURE ELEMENTS AND PATTERNS



CRISTAE

l ≥ 2b

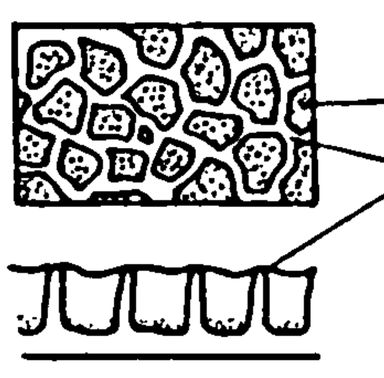
FIG. 26



RUGULAE

l > 2b , d ≥ 2h

FIG. 27



RETICULUM

FIG. 28

b = WIDTH d = DIAMETER h = HEIGHT l = LENGTH

TEXT FIG. 4 — 5

BIFORM ELEMENTS The term was used by Richardson (1965, p. 568) in the description of the genus Dibolisporites. This is an ornamental element which shows the combination of two or more quite different styles e.g. cone surmounted by spine, as in Dibolisporites sp. (text fig. 6.1) and Samarisporites sp. (text fig. 6. 5b).

MURORNATE SCULPTURE ELEMENTS AND PATTERNS

CRISTAE Elevations of the surface with elongate (at least 2 times as long as broad) curved bases; occasionally fusing together to form an irregular reticulum; tops of elements more or less pointed or serrated to slightly rounded (fig. 26).

CRISTATE SCULPTURE A sculptural pattern formed by cristae.

RUGULAE Elevations with elongated bases (at least 2 times as long as broad), bases curved or irregular in surface view; greatest dimension of bases at least 2 times the height; tops flat to slightly rounded (fig. 27).

RUGULATE SCULPTURE A sculptural pattern formed by rugulae.

MURI The elevations bounding the lumina of reticulate sculptural patterns (fig. 28). In profile the sides of the elevations may be parallel, converging or diverging and the tops rounded, flat or pointed.

LUMINA The pits (depression) between the elevations of a reticulate sculptural pattern. The lumina of a reticulum can be either almost rounded or polygonal in surface view (fig. 28).

RETICULATE SCULPTURE = reticulum = the sculptural pattern formed by muri and adjoining lumina.

CHAPTER 5

NOMENCLATURE AND CLASSIFICATION OF SPORES

NOMENCLATURE AND CLASSIFICATION OF SPORES

"All classification systems are artifices designed for purposes of mankind". Schopf (in Tschudy & Scott 1969, p. 52), or as stated with broader implications by Haggett (1966) "order and chaos are not part of nature, but part of the human mind". Classification is however necessary, as the approach of placing each individual into a separate category is most unsatisfactory and of little use. Scientists are constantly trying to invent new and more efficient categories in which to pigeon-hole reality more accurately.

Palynology suffers from this classification problem. The major difficulties are associated with the species concept, and the numerous synonyms are misidentifications which have crept into the literature. Species are the basis of all palaeontological studies, not least palynology. Every worker has his own concept of what constitutes a genus or species. Certain workers tend to subdivide or "split" excessively whilst others tend to "lump" too broadly.

A purely morphographic classification is used throughout the present work and, for purposes of maintaining precision in scientific communication, the nomenclature of spore dispersae is determined by the rules of priority and typication as laid down in the International Code of Botanical Nomenclature (ICBN) 1966. The Present writer supports the views expressed by Hughes (1969, p. 141) that genera preferably should be restricted to gross time limits as "lumping" only produces large, unwieldy genera which furthermore appear to serve no real advantage for studying palaeoecological evolution. In the present work contrary to Staplin (1960, p. 14)

and McGregor (1973, p. 16) a Palaeozoic form genus Leiotriletes (Naumova) Potonié & Kremp (1954) is treated as a coherent generic entity rather than a synonymous form of a mesozoic genus Deltoidospera Miner (1935).

Schopf (1969, pp. 58-63) concludes that taxonomy based on plant microfossils is difficult, however, owing to uncertainty as to which morphological characters represent close heredity alliance and which arose by convergence. Due to lack of evidence regarding the natural affinities of the majority of miospores, an artificial system of nomenclature and classification, based on morphographical features is generally accepted as being the most efficient method of classifying miospores in the Palaeozoic. If spores are found in situ the morphographic system is still retained, partly from convention and partly because of the fact discovered by L.R. Moore (1946) that widely different morphological spore forms were produced in one (Carboniferous) sporangium. This system is limited in that it has been designated to fulfil biostratigraphic needs with no regards as to the relative phyletic significance of the various morphological characters. Consequently, these schemes have little value for studies on plant evolution or palaeoecology.

All the spores described in this thesis come into the major subdivision of Anteturma sporites. Spores included in this category can be further subdivided according to size i.e. miospores ($<200\mu m$) and megaspores ($>200\mu m$). The division between is purely arbitrary (Guennel 1952) and not related to botanical function.

The following five major suprageneric classification systems of the Anteturma sporites H. Potonié are in use. (1) Naumova (1939) (2) Potonié & Kremp (1954) (3) Dettmann (1963) (4) Neves & Owens (1966) (5) Smith & Butterworth (1967).

Naumova's system is generally used in the U.S.S.R. whilst those defined by the others are followed elsewhere. Naumova (loc. cit.) followed the generic classification of Luber & Waltz (1938) and her suprageneric grouping is based on the presence or absence of a 'margin' coupled with the nature of the dehiscence mark. Because genera or subgroup were found to be too broad, they have been redefined or accommodated into other systems. The more important of these with regard to the present study include Leiotriletes, Acanthotriletes, Dictyotriletes, rediagnosed by Potonié & Kremp (1954). Hymenozonotriletes and Lophozonotriletes redefined by Potonié & Kremp (1958); and Archaeozonotriletes redefined by Potonié (1958) and Allen (1965).

The most widely used and sophisticated suprageneric classification is that instituted by Potonié & Kremp (1954), hence followed in the present work. This scheme is summarised in table 5.I.

The system of classification outlined by these authors is based on sutural features, wall stratification, equatorial thickening and/or equatorial extension of the exine and the exine sculpture.

Dettmann (1963, p. 15) made an attempt to revise this system (see table 5-2) in which the dehiscence mark and stratification of the exine are used to define the turma and suprasubturma respectively. Equatorial features are used to divide the spores into subturma. The infraturma is based on sculptural features, equatorial thickening and/or equatorial extension of the exine.

Concerning the use of the root "Perino" of Erdtman (1947) in Dettmann's system of classification, many palynologists e.g. Richardson (1965, p. 585), Neves & Owens (1966, p. 339) and Smith & Butterworth (1967, p. 107) agree that it should be confined to miospores with a perispore or perisporal membrane e.g. Perotriletes,

DIAGNOSTIC FEATURES	CATEGORY															RANK
	SPORITES															ANTETURMA
APERTURE LIP FEATURES EQUATORIAL FEATURES	TRILETES							BARBA-TES	ZONALES				MONOLETES		CYSTITES	TURMA
LIP FEATURES STRATIFICATION EQUATORIAL FEATURES	AZONOTRILETES			LAGENOTRILETES	PYROBOLOTRILETES	CAPULITRILETES	PERINOTRILETES		AURITOTRILETES		ZONOTRILETES		AZONOMONOLETES		ZONOMONOLETES	SUBTURMA
LIP FEATURES SCULPTURE EQUATORIAL FEATURES	LAEVIGATI	APICULATI	MURORNATI	GULATI					AURICULATI	APPENDICIFERI	CINGULATI	ZONATI	PATINATI	LAEVIGATOMONOLETI	SCULPTATOMONOLETI	PERINOMONOLITI			INFRATURMA

TABLE 5.1. THE SUPRAGENERIC CLASSIFICATION OF THE ANTETURMA SPORITES BY POTONIÉ & KREMP 1954 FROM DETTMANN 1963.

DIAGNOSTIC FEATURE	CATEGORY										RANK
	SPORITES										ANTETURMA
APERTURE	TRILETES							MONOLETES		HILATES	TURMA
STRATIFICATION	ACAVATITRILETES						PERINO-TRILITES	ACAVATO-MONOLETES		PERINO-MONOLI-TES	SUPRA - SUBTURMA
EQUATORIAL FEATURES	AZONOTRILETES			ZONOTRILETES				AZONOMONOLETES	ZONOMONOLETES		SUBTURMA
SCULPTURE / EQUATORIAL THICKENING AND/ OR EXTENSION	LAEVIGATI	APICULATI	MURORNATI	AURICULATI	TRICRASSATI	CINGULATI	PATINATI		LAEVIGATOMONOLETI	SCULPTATOMONOLETI	INFRATURMA

TABLE 5.2. THE SUPRAGENERIC CLASSIFICATION OF THE ANTETURMA SPORITES BY DETTMANN 1963

which are distinct enough to be classified separately.

To solve the problem Smith & Butterworth (1967), see table 5.4 , modified Dettmann's scheme by introducing at supra-subturma level, the terms Laminatitriletes, for spores in which the two layers of exine (exoexine and intexine) are in close contact, and Pseudosaccatitriletes Richardson, where the two layers are separated to form a peripheral cavity. The infraturma defined by Smith & Butterworth (loc. cit.) is based on sculptural features, equatorial thickening and/or equatorial extension of the exine.

Neves & Owens (1966, p. 338), table 5-3, rejected the term cavate sensu, Dettmann (1963) which was originally proposed by Faegri & Iverson (1950, p. 160) as, "ektexine loosened from endexine, columellae sticking to the under surface of the tectum", and replaced by the term camerate for structures referred to by Dettmann as cavate. Neves & Owens (loc. cit.) reserved the term cavate for pollen grain where, when two layers of exine separate, the characteristic pattern is produced.

The suprasubturma Cameratitriletes Neves & Owens (1966) is divided into the subturmae Solutitriletes and Membranatitriletes. The intexine is attached to the exoexine only over the proximal surface in the former; in the latter category spores are classified where both layers of exine are attached proximally and distally, developing a single peripheral chamber.

The drawback in the classification proposed by Neves & Owens is the difficulty one encounters when determining the nature of the attachment or the separation of intexine from exoexine without thin sectioning.

None of these suprageneric classifications can be regarded as perfect. The Smith & Butterworth's system is used in preference to that given by Neves & Owens in the systematic description of

DIAGNOSTIC FEATURE	CATEGORY										RANK
	SPORITES										ANTETURMA
APERTURE	TRILETES							MONO LETES	HILATES		TURMA
STRATIFICATION	ACAMERATITRILETES (NOV.)		CAMERATITRILETES (NOV.)					PERINO TRILITES			SUPRA SUBTURMA
EQUATORIAL FEATURES / MEMBRANE ATTACHMENT	AZONOTRILETES	ZONOTRILETES	SOLUTITRILETES (NOV.)		MEMBRANATITRILETES (NOV.)						SUBTURMA
SCULPTURE / EQUATORIAL THICKENING AND/OR EXTENSION	LAEVIGATI, APICULATI, MURORNATI, ETC.	TRICRASSITI, CINGULATI, ZONATI, ETC.	PLANATI (NOV.)	DECORATI (NOV.)	CONTINUATI (NOV.)	CINGULICAMERATI (NOV.)	MEMBRANATI (EMEND.)	POLYCAMERATI (NOV.)			INFRATURMA

TABLE 5.3. THE SUPRAGENERIC CLASSIFICATION OF THE ANTETURMA SPORITES BY NEVES & OWENS 1966.

DIAGNOSTIC FEATURE	CATEGORY														RANK
	SPORITES														ANTETURMA
APERTURE	TRILETES						MONOLETES			HILATES			ALETES		TURMA
STRATIFICATION	ACAVATITRILETES		LAMINATITRILETES		PSEUDO-SACCI-TRILETES	PERINO-TRILETES	ACAVATO-MONOLETES		CAVATO MONO LETES	ACA-VATI-HILATES	CAVATI-HILATES				SUPRA-SUBTURMA
	AZONOTRILETES	ZONOTRILETES	AZONOLAMINATITRILETES	ZONOLAMINATITRILETES			AZONOMONOLETES	ZONOMONOLETES			AZONOCAVATIHILATES	ZONOCAVATIHILATES			SUBTURMA
SCULPTURE / EQUATORIAL THICKENING AND/OR EXTENSION	LAEVIGATI APICULATI MURORNATI	AURICULATI TRICRASSATI CINGULATI	TUBERCULORNATI	CRASSITI CINGULICAVATI PATINATI	MONOPSEUDOSACCITI POLYSPEUDOSACCITI		LAEVIGATOMONOLETI SCULPTATOMONOLETI				EMTYGMATI OPERCULATI				INFRATURMA

TABLE 5.4. THE SUPRAGENERIC CLASSIFICATION OF THE ANTETURMA SPORITES BY SMITH & BUTTERWORTH 1967.

the present work.

Corsin et al. (1962) proposed the emendation of all generic names to give a standardised nomenclature in which spore and pollen names terminated in "sporites" and "pollenites" respectively. This suggestion is ignored here because of the work involved in emending the present system, and the difficulty in distinguishing between spores and pollen grains.

Concurring with Neves & Owens (loc. cit.), Grebe (1971, pp. 15,16) also suggested that spores exhibiting separation of the exine layers are cavate and that camerate and saccate are two forms of cavate; in camerate spores the two exine layers are unaccompanied by columellate infrastructure while in saccate spores infrareticulate structural pattern occurs between the two layers.

CHAPTER 6

SYSTEMATIC DESCRIPTIONS

SYSTEMATIC PALYNOLOGY

This chapter presents a systematic account of the taxa recorded during the present investigation. Suprageneric classification of the Anteturma Sporites follows the scheme of Potonié & Kremp (1954), with certain revisions and innovations proposed by Dettmann (1963), Smith & Butterworth (1967) and Streel (in Becker, Bless, Streel & Thorez 1974). The terms of Grebe (1971) are used here, most of which are defined in the glossary of Kremp (1965). The species are listed in alphabetical order within each genus.

Where possible, systematic description are based on at least thirty adequately preserved specimens. Likewise size ranges (dimensions) are given for thirty or more specimens, and the mean (average size) calculated. The size ranges of species which were recorded in insufficient numbers for this treatment are given as an overall size range of the specimens recorded. The size range given in the dimensions is the maximum diameter of the spore, and does not include the ornament unless otherwise stated. Micron is abbreviated to 'μ m' throughout. Scanning electron microscope is abbreviated to 'SEM'.

The subheading 'Description', as used in the systematic, signifies a summary of salient features of specimens assignable to the taxon cited and recorded during the present investigation. Diagnoses are given, in addition to a 'Description', for the microfossils recorded for the first time.

An effort has been made to illustrate the morphological variations within a species or a genus described here. Some species have been studied with the help of the scanning electron microscope (SEM). SEM photomicrographs have been useful in understanding the

surface sculpture of miospores, whereas the light photomicrographs are essential to illustrate the sporewall structure below the surface.

The stratigraphic occurrence of each of the species recorded together with miosphore zones, established during the present investigation, is shown in tabular form in table 7.1 .

Anteturma SPORITES H. Potonié 1893

Turma TRILETES Reinsch 1891

Subturma AZONOTRILETES Luber 1935

Infraturma LAEVIGATI Bennie & Kidston emend.
Potonié & Kremp 1954

Genus CALAMOSPORA Schopf, Wilson & Bentall 1944

Type Species: C. hartungiana Schopf in Schopf, Wilson & Bentall 1944

Diagnosis: See Schopf in Schopf, Wilson & Bentall 1944, p. 51.

Remarks: The genus is instituted to incorporate miospores possessing a thin exine which is laevigate and usually intensely folded with relatively short laesurae, generally less than one half of the total spore radius in length. A number of species have been erected for the genus exhibiting quite a few distinguishing features. Other than size, specification is based on the nature and extent of folding, thickness of exine, non-polar compression and length of laesurae. In this sytem of classification, which is purely based on morphographic characters, the genus has been excessively subdivided without serving any stratigraphical purpose .

Comparison: Calamospora differs from Phyllothecotriletes Luber 1955 and from Punctatisporites (Ibrahim) Potonié & Kremp, in having pronounced secondary folding. In Phyllothecotriletes the exine is thicker while Punctatisporites has longer laesurae, and no contact area.

Calamospora liquida Kosanke 1950

Plate 1, fig. 1

1950 Calmospora liquida Kosanke p. 41, pl. 9, fig. 1.

Occurrence: Rare. Chadakoin Formation, (Dexterville Member), Pennsylvania, U.S.A.

Diagnosis: See Kosanke 1950, p. 41.

Size range: 65-75μm (10 specimens measured).

Remarks: This speices is characterized by straight suturae longer than half the spore radius in length which may be accompanied by very narrow labra.

Comparison: Calamospora liquida is distinguished from other species of the genus Calasmospora by the length of its trilete mark which is longer, and lacking darkened contact areas. C. microrugosa comes closest morphologically to the present form but differs, however, on the seemingly slight ground that it possesses shorter laesurae. Recently identical specimens have been recovered from Upper Devonian and Lower Carboniferous sediments of Southern Ireland (Higgs, 1975).

Calamospora nigrata (Naumova) Allen 1965

Plate 1, fig. 2

1953 Leiotriletes nigratus Naumova pp. 23, 43, pl. 1, fig. 9 and pl. 5, figs. 5 & 6.

1955 Trachytriletes nigratus (Naumova) Kedo p. 20, pl. 1, fig. 10.

1958 Leiotriletes nigratus Ishchenko p. 35, pl. 1, fig. 5.

1965 Calamospora nigrata (Naumova) Allen p. 693.

1966 Phyllothecotriletes nigratus (Naumova) De Jersey p. 6, pl. 1, figs. 7&8.

1967 Calamospora cf. nigrata (Ishchenko) Butterworth & Spinner p. 3, pl. 1, fig. 5.

1970 Calamospora sp. cf. C. nigrata (Naumova) Brideaux & Rodforth p. 31, pl. 1, fig. 7.

1971 Calamospora nigrata (Naumova) Allen, Clayton M.S. p. 24, pl. 1, fig. 6.

Occurrence: Chadakoin and Cattaraugus Formations.

Diagnosis: See Naumova 1953 p. 23.

Description: Miospores radial trilete; amb sub-circular, margin smooth. Exine thin, laevigate, commonly folded. Contact areas darkened. Trilete mark distinct; laesurae straight, simple, extending ½ to ⅔ spore radius.

Size range: 50-70 μm, mean 60 μm (35 specimens measured).

Remarks: Naumova and Ishchenko, apparently working independently, both described Leiotriletes nigratus as a new species. Some workers, e.g. Brideaux & Radforth (1970), regard the specimens described from the Russian Platform by Naumova (1953) as distinct from those observed by Ishchenko (1958) from the Upper Devonian and Tournaisian of the Dnieper-Donetz Basin. The present writer agrees with William (in Clayton, M.S. 1971, p. 25) that these two species are synonymous though the miospores observed by Ishchenko were larger (90-110 μm) than those described and illustrated by Naumova (60-70 μm). The species described by Naumova (loc. cit.) as senior synonym takes priority over those recorded by Ishchenko (loc. cit.).

Calamospora pedata Kosanke 1950

Plate 1, figs. 3 & 4

1950 Calamospora pedata Kosanke p. 42, pl. 9, fig. 3.

1967 Calamospora pedata Kosanke, Smith & Butterworth p. 136, pl. 2, fig. 7.

Occurrence: Upper part of Canadaway and Chadakoin Formations.

Diagnosis: See Kosanke 1950 p. 42.

Description: Miospores radial trilete; amb sub-circular to sharply lenticular, margin smooth. Exine laevigate, up to 2.5 μm thick with one major fold. Trilete mark distinct; laesurae simple, straight extending ⅔ spore radius.

Size range: 44-60 μm, mean 52 μm (30 specimens measured).

Remarks and Comparison: A single prominent fold and a relatively thick exine are the characteristic features of the species. Punctatisporites arcticus McGregor (1960 p. 28, pl. 11, fig. 5) probably exhibits a single large fold (not mentioned in the 'Description') and falls within the size range quoted by Kosanke. The Canadian form may be synonymous, but until a direct comparison of the type is possible a more precise assignment of the McGregor's species is precluded.

Genus LEIOTRILETES (Naumova) Potonié & Kremp

Type Species: L. sphaerotriangulus (Loose) Potonié & Kremp 1954.

Diagnosis: See Potonié & Kremp 1954, p. 120.

Remarks: The genus includes miospores having a triangular amb, unornamented exine with laesurae usually more than half the spore radius. Staplin (1960) McGregor & Owens (1966) and McGregor (1973) placed spores of this form in Deltoidospora Miner (1935), attempting to link the Palaeozoic and post-Palaeozoic nomenclature. Here the accepted Palaeozoic nomenclature is retained, as by Smith & Butterworth (1967). Chaloner & Streel (1966) and many others, because the problem is not confined to Leiotriletes as pointed out by Playford (1962, p.573). Spores substantially similar to Leiotriletes occur from Devonian to Recent e.g. Deltoidospora in the Triassic.

Leiotriletes ornatus Ishchenko 1956

Plate 1, fig. 5

1956 Leiotriletes ornatus Ishchenko p. 22, pl. 2, figs. 18-21.

Occurrence: Occurs inconsistently in all four of the formations studied.

Diagnosis: See Ishchenko 1956, p. 22.

Description: Miospores radial trilete; amb sub-triangular with convex sides and rounded apices. Exine up to 2μm thick and laevigate. Trilete mark distinct; laesurae straight masked with folds up to

3μm wide extending almost to the radius of spore.

Size range: 30-45μm, mean 39μm (35 specimens measured).

Remarks: The specimens recorded during the present investigation conform closely with Ishchenko's diagnosis (p. 22). Ischenko states that exine is thin in L. ornatus. The species has been recorded from a variety of places by different authors and the ranges of exine thickness quoted by Playford (1962, p. 575), Sullivan (1964, p. 1251), and Felix & Burbridge (1967, p. 354), are 2-3.5μm, 3μm and 2-3μm respectively. In the opinion of the present writer, the figures quoted by subsequent authors seem to be excessive for this species. Ishchenko described a trilete with "narrow thickenings" so that the specimen figured by Felix & Burbridge (1967, pl. 53, fig. 3) and spore type 1 of Love (1960, p. 122, pl. 2, fig. 9, text figure 12) are probably not of this species. Kaiser (1970, pl. 16, fig. 7) recorded L. ornatus from Lower Carboniferous sediments of Bear Island which appears to be thin walled and falls within Ishchenko's circumscription of L. ornatus. A specimen figured by Paproth & Streel (1970, pl. 25, fig. 6) could be identical to Ishchenko's species.

Leiotriletes tortilus Playford 1964

Plate 1, fig. 6

1964 Leiotriletes tortilus Playford p. 6, pl. 1, figs. 1-4.

1973 Punctatisporites tortilus (Playford) Varma p. 304, pl. 1, fig. 3.

Occurrence: Rare. Canadaway Formation, New York State, U.S.A.

Diagnosis: See Playford 1964, p. 6.

Description: Miospores radial trilete; amb sub-triangular with convex sides and almost rounded apices. Exine approximately 2.5μm thick, proximal surface laevigate, distal hemisphere appears moderately granulate, probably best described as scabrate. Trilete mark distinct, laesurae perceptible simple, sinuous, length unequal even on the same specimen, $\frac{3}{4}$ to full spore radius.

Size range: Two specimens recorded measuring 40 and 43.3μ m respectively.

Remarks: In transferring the miospores, Varma (1973, p. 304) interprets the amb of the species as being circular to subcircular. It is of interest to note that a single specimen illustrated by Varma on pl. 1, fig. 3, is not of the type as seen in Punctatisporites. On the basis of the sub-triangular equatorial outline, observed during the present investigation, the original attribution to the genus Leiotriletes is retained here.

Genus PUNCTATISPORITES (Ibrahim) Potonié & Kremp 1954

Type Species: P. punctatus Ibrahim 1933.

Diagnosis: See Potonié & Kremp 1954, p. 120.

Remarks: This genus includes laevigate spores with a circular to subcircular amb. The suturae are generally longer than half the spore radius.

Punctatisporites glaber (Naumova) Playford 1962

Plate 1, fig. 7

1938 Azonotriletes glaber (Naumova) Waltz in Luber & Waltz p. 8, pl. 1, fig. 2 and pl. A, fig. 3.

1952 Leiotriletes glaber (Waltz) Ishchenko p. 13, pl. 2, figs. 15&16.

1955 Calamospora glaber (Naumova) Potonié & Kremp p. 47.

1956 Leiotriletes glaber Naumova, Ishchenko p. 18, pl. 1, figs. 7&8.

1960 Punctatisporites curviradiatus Staplin p. 7, pl. 1, figs. 17&20.

1962 Punctatisporites glaber (Naumova) Playford p. 576, pl. 78, figs. 15&16.

1965 Punctatisporites sp. D. Upshaw & Creath p. 436, pl. 1, fig. 10.

Occurrence: Java, Canadaway, Chadakoin and Cattaraugus Formations; New York State and Pennsylvania, U.S.A.

Diagnosis: See description by Playford 1962, p. 576.

Description: Miospores radial trilete; amb circular to sub-circular, margin smooth. Exine laevigate 1-2μm thick, sometimes appearing shagrinate, which may be the result of corrosion pitting, rarely folded. Specimens variously oriented. Trilete mark distinct; laesurae straight, simple, extending $\frac{1}{3}$ to $\frac{2}{3}$ spore radius.

Size range: 30-55μm, mean 43μm, (50 specimens measured).

Remarks: The species has widely been reported from the area investigated, showing different mode of preservations. The present writer departs from Playford (1962) in accommodating P. nitidus Hoffmeister, Staplin & Malloy (1955) within the morphographic range of P. gl ber. The character of the species under consideration should be restricted to laevigate exine while minutely granulose forms can well be classified separately.

Punctatisporites minutus Kosanke 1950

Plate 1, figs. 8 & 9

1950 Punctatisporites minutus Kosanke p. 15, pl. 16, fig. 18.

Occurrence: Java, Canadaway, Chadakoin and Cattaraugus Formations; New York State and Pennsylvania, U.S.A.

Diagnosis: See Kosanke 1950, p. 15.

Description: Miospores radial trilete; amb almost circular having smooth periphery. Exine 1-1.5μm thick. Variously folded, laevigate to finely infrapunctate. Trilete mark distinct; laesurae straight, simple or labrate, lips slightly developed, length of rays $\frac{1}{2}$ to $\frac{3}{4}$ spore radius

Size range: 20-30μm, mean 25μm (60 specimens measured).

Remarks: The species is frequent when encountered.

Comparison: The present form appears to be identical to P. nitidus Hoffmeister, Staplin & Malloy (1955) but the latter differs in being larger (31-43μm) and possessing a laevigate to faintly granulose exine. Comparison can be made with P. platirugosus (Waltz) Sullivan (1964b)

but the Russian species is characterized by having compression folds, particularly in equatorial regions.

Punctatisporites platirugosus (Waltz) Sullivan 1964b

Plate 1, figs. 10 & 11

1941 Azonotriletes platirugosus Waltz in Luber & Waltz pl. 1, fig. 1.

1956 Leiotriletes platirugosus (Waltz) Ishchenko pl. 1, fig. 1.

1958 Leiotriletes platirugosus (Waltz) Ishchenko pl. 1, fig. 1.

1964 Punctatisporites platirugosus (Waltz) Sullivan p. 358, pl. 57, figs. 7-9.

Occurrence: Occurs sporadically in all four of the formations studied.

Diagnosis: See description by Sullivan 1964b, p. 358.

Description: Miospores radial trilete; amb circular, subcircular to oval, margin smooth. Exine laevigate 1-1.5μ m thick. Consistently strongly folded in the equatorial regions. Trilete mark distinct; laesurae straight, simple or associated with folds, rays extending $\frac{3}{4}$ spore radius.

Size range: 22-39μ m, mean 30μ m (30 specimens measured).

Remarks: Only a few specimens have been observed during the course of the present study which conform with those recorded by Russian workers and by Sullivan (1964b). P. platirugosus can be distinguished from P. minutus in having distinct patterns of folding around the equator. The miospores described above correspond to var. minor. Specimens described and figured by Bertelsen (1972 p. 27, pl. 1, figs. 6 & 7) may be identical with the Russian species.

Punctatisporites solidus

Plate 1, fig. 12

1957 Punctatisporites solidus Hacquebard p. 308, pl. 1, fig. 13.

Occurrence: Cattaraugus Formation, Pennsylvania, U.S.A.

Diagnosis: See description given by Hacquebard 1957 p. 308.

Description: Miospores radial trilete; amb subcircular, margin smooth. Exine 4μ m thick at equator; laevigate to finely infrapunctate. Trilete mark distinct; laesurae accompanied by slightly raised lips, extending $\frac{3}{4}$ spore radius.

Size range: One specimen seen measuring 45μ m.

Comparison: The only specimen recorded differs from other species in possessing thicker exine.

Punctatisporites stabilis Playford 1962

Plate 1, fig. 13

1962 Punctatisporites stabilis Playford p. 578, pl. 79, figs. 1&2.

Occurrence: Canadaway Formation (N.E. Shale Member) and Chadakoin Formation, New York State and Pennsylvania, U.S.A.

Size range: 65-75μ m (10 specimens measured).

Remarks: Only a few specimens have been observed during the course of the present investigation which closely resemble Playford's (1962) diagnosis excepting the nature of laesurae which are indiscernible in some of the specimens from U.S.A. Where perceptible, extending for $\frac{1}{2}$ to $\frac{3}{4}$ of radius. Specimens show oblique orientation.

Infraturma RETUSOTRILETI Streel (in Becker et al) 1974

Genus RETUSOTRILETES (Naumova) Richardson 1965

Type Species: P. pychovii Naumova 1953

(lectotype species of Richardson 1965)

Diagnosis: See Richardson 1965 p. 563

Remarks:

Naumova (1953) established a genus (subgroup) Retusotriletes embracing subcircular trilete miospores with distinct contact areas, possessing both laevigate and sculptured exines. This author did not designate a genotype and therefore the genus was regarded as nomen numdum. Though Potonié (1958) did not formally emend this genus he selected type species R. simplex Naumova (1953, pl. 2, fig. 9), the first described of Naumova's ten species, and restricted the use of taxon to forms with smooth exine. Since then many workers have commented upon the circumscription of Retusotriletes including Chibrikova (1959), Chaloner (1963), Playford (1964), Streel 1964, 1967, Richardson 1965, Mortimer (1967), Lanninger (1968), Schultz (1968), Riegel (1968), Cramer (1969), Richardson & Lister (1969), Owens (1971), McGregor (1973) and Tiwari & Schaarschmidt (1975). At present there are two schools of thought and palynologists may follow either of them concerning the delimitation of the genus Retusotriletes. First, Streel (1964) emended the genus and followed Potonié in using R. simplex Naumova as type species. Richardson & Lister (1969, p. 214) pointed out that Potonié's arbitrary selection of Naumova's R. simplex was unfortunate in that Naumova's illustrations pl. 2, fig. 9 and pl. 15, fig. 14 lack curvaturae perfectae and therefore distinct contact areas. R. simplex is therefore not characteristic of this genus. Secondly, Richardson

(1965) independently of Streel, emended the genus suggesting R. pychovii Naumova (p. 953, pl. 19, fig. 5) as the type species.

The present writer follows Richardson (loc. cit. p. 564) on the grounds that the lectotype possesses well defined contact areas delimited by curvaturae perfectae. The emendation proposed by Streel (1964) is not followed here as the lectotype of Potonié lacks the diagnostic features of the genus.

Comparison:

Retusotriletes (Naumova) Richardson (1965) differs from Apiculiretusispora (Streel 1967, p. 32) and Verruciretusispora Owens (1971, p. 20) by having laevigate exine.

Retusotriletes caperatus sp. nov.

Plate 1, figs. 14-19

Derivation of name:

Latin, Caperatus, meaning wrinkled, referring to the small wrinkles on the miospores.

1970 Retusotriletes sp. McGregor pl. 21, fig. 8.

1974 Retusotriletes sp. A. Streel in Becker et al. p. 24, pl. 15, figs. 11-12.

Holotype: Pl. 1, figs. 15-16: US6E 300 111649.

Type Locality: Pope Hollow Section; along boundary between Carroll and South Vally Townships, Jamestown quadrangle, New York State.

Occurrence: Chadakoin and Cattaraugus Formations, New York State, U.S.A.

Diagnosis:

Miospores with an apical lighter zone surrounded by a triangular dark area marked with radial thin folds, rarely extending to the equator; ends of laesurae connected with curvaturae perfectae.

Description:

Miospores radial trilete; amb circular, subcircular to oval, margin smooth. Exine 1-2μm thick infrapunctate. Distal surface smooth. Proximal surface with well marked contact areas, bounded by curvaturae perfectae, 1μm thick and raised, coincident with equator except the radial areas. Spore apex has a dark triangular area, 3-5μm wide, extending $\frac{1}{2}$ to $\frac{3}{4}$ spore radius, surrounding an inner apical lighter zone; within the contact areas proximal zones (inner lighter and outer dark) are marked by irregularly radially arranged folds up to 1μm thick, 5-15μm long, rarely extending to the equator. Contact areas 17-25μm wide. Trilete mark distinct; laesurae straight, simple, extending $\frac{3}{4}$ spore radius, rarely accompanied by folds, 1-2μm thick, reducing towards equator.

Size range: 40-54μm, mean 46μm (40 specimens measured).

Remarks:

Laevigate exine together with distinct curvaturae perfectae renders appropriate the assignment of this species to the genus Retusotriletes.

Comparison:

The present form can be distinguished from other representatives of the taxon by possessing thin folds on the proximal surface. Of previously described forms, Emphanisporites epicautus Richardson & Lister (1969) seems to be the most closely similar. The latter species differs, however, in having well defined radial muri and a smaller size range (25-40μm).

Retusotriletes sp. cf. R. concinnus
Kedo 1955 in Lanninger 1968

Plate 2, figs. 1-3

? 1955 Retusotriletes concinnus Naumova in litt. Kedo
pl. 1, fig. 13

I968 Retusotriletes concinnus Naumova in litt; Lanninger pl. I, fig. 16

I972 Retusotriletes cf. R. concinnus Naumova in lit; Kemp p. I09, pl. 52, fig. I.

Occurrence: Rare. Chadakoin Formation, Pennsylvania, U.S.A.

Description: Miospores radial trilete; amb circular to oval with rounded apices and convex sides. Margin smooth. Exine laevigate and up to 4μm thick. Contact areas delineated by curvaturae that may be confined entirely to the proximal surface , or may be confluent with the equator along most of their length. In the latter case the curvaturae show as Y-like invaginations at the ends of the laesurae. On some specimens the terminations of the suturae are connected by curvaturae that appear interradially as a thin line. Occasionally a lighter ?thinner zone is present on or in the vicinity of the proximal pole. Trilete mark distinct; laesurae sinuous, or rarely straight, extending to the spore radius, occampanied by a narrow labra I.5-2.5μm raised, rays terminating in curvaturae.

Size range: 36 - 56μm, mean 48μm (25 specimens measured).

Remarks and comparison: The specimens described above appear to be closely akin to those recorded from Germany (Lanninger I968) and Antarctica (Kemp I972). Decisive allocation is not made here to the previously described forms, however, owing to the different (smaller) size range of the miospores recorded during this study. The dimensions given by Lanninger (loc. cit.) and Kemp (loc. cit.) are 65 μm and 63-84μm respectively.

Retusotriletes concinnus Naumova in Kedo (I955, pl. I, fig. I3) is different from those observed from Germany, Antarctica and U.S.A. (present study) with respect to morphographic circumscriptions and in the nature of laesurae. Present examples also bear some resemblance to Retusotriletes leptocentrum Higgs (I975) described from southeast Ireland. In the Irish specimens a lighter apical area is, however, a feature not normally associated with the present form.

Retusotriletes concretus nom. nov.

Plate 2, fig. 5.

Derivation of name: Latin, concretus, meaning thick, referring to the thick triangular apical area.

1963 Retusotriletes novus Shepeleva p. 90 (invalid: I.C.B.N. article 33)

1969 Retusotriletes cf. triangulatus Streel in Richardson & Lister p. 217, pl. 37, figs. 3-5.

Occurrence: The Canadaway, Chadakoin and Cattaraugus Formations; New York State and Pennsylvania, U.S.A.

Description: Miospores radial trilete; amb circular to subcircular. Exine laevigate and 1-2μm thick; in some specimens folds are present along the part of the equatorial margin. Contact areas delimited by distinct curvaturae which usually follow the equatorial margin except in the radial areas in polar compression. Curvaturae 1-1.5μm thick and raised. Trilete mark distinct, surrounded by a thickened dictinctly triangular area in the apical region; the apical area extends almost to the tip of the rays; laesurae straight, frequently splayed open, continued as dark lines to the curvaturae, total length of suturae $\frac{3}{4}$ of the spore radius.

Size range: 44-60μm, mean 51μm (30 specimens measured)

Remarks and Comparison: Markedly triangular apical area and dark, raised curvaturae are the distinguishing features of the species described above.

Retusotriletes goensis Lele & Streel 1969

Plate 2, fig. 4

1969 Retusotriletes goensis Lele & Streel p. 93, pl. 1, figs. 12-16

cf. 1973 Retusotriletes cf. goensis Lele & Streel; Richardson & Ioannides p. 271, pl. 1, figs. 1-6.

Occurrence:

Rare. In Java, Chadakoin and Cattaraugus Formations, New York State, U.S.A.

Diagnosis: See Lele & Streel p. 93.

Description:

Miospores radial, trilete; amb subcircular to subtriangular with markedly convex sides and rounded apices, margin smooth. Exine up to 2.5μm thick, laevigate to finely infragranulate. A dark (? thickened) area of subcircular to subtriangular outline at the proximal pole extends about half way to the tips of the rays. Trilete mark distinct; laesurae simple, straight, extending almost to the equator, terminating in curvaturae perfectae, which are coincident with the equator for most of their length (excepting the radial region). Curvaturae well defined in oblique compressions.

Size range: 40-60μm, mean 52μm (35 specimens measured).

Remarks and Comparison:

McGregor (1973, p. 20) regarded Retusotriletes goensis Lele & Streel (1969) as a synonym of R. rotundus (Streel) Streel. In the present work the former is treated as a separate entity on the basis of seemingly slight morphographic features, such as a darker apical area, contrasting with the lighter apical area surrounded by a darker zone in R. rotundus. However, it is possible that the two species are end members of variation within one complex.

The species has also been reported from Upper Devonian deposits of the U.S.A. (Curry, 1975) and western Libya (Massa & Moreau-Benoit, 1976).

The present form differs from R. concretus nom. nov. in having a smaller apical area which does not extend to the tip of the rays. The specimens of this study possess subcircular to subtriangular apical thickening rather than a distinctly triangular area.

Retusotriletes sp.

Plate 2, figs. 6-7

Occurrence:

Rare, Canadaway and Chadakoin Formations, New York State and Pennsylvania, U.S.A.

Description:

Miospores radial, trilete; amb subcircular to roundly triangular. Exine up to 2 µm thick, laevigate to shagrinate, which may be the result of corrosion pitting. Contact areas laevigate, frequently and distinctly darkened (thickness), one-half to two-thirds of spore radius. Trilete mark distinct; laesurae straight, simple or labarate, rarely gaping, extending $\frac{3}{4}$ of spore radius. End of the rays connected by curvaturae within 2-3 µm of the equator.

Size range: 35-79 µm, mean 54 µm (30 specimens measured).

Remarks & Comparison:

Exine appears to be corroded in the areas of laesurae and curvaturae perfectae. The specimens referred to Phyllothecotriletes sp. in Lanzoni & Magloire (1969) are probably identical to the present form. Miospores similar to Retusotriletes sp. were also found dispersed in Southern Ireland by Higgs (1975, p. 395, pl. 1, figs. 9-13).

Genus APICULIRETUSISPORA Streel 1964 emend. Streel 1967

Type species: A. brandtii Streel 1964.

Diagnosis: See Streel 1967, p. 32.

Remarks:

The genus Apiculiretusispora was instituted to incorporate sculptured trilete miospores coupled with curvaturae perfectae or imperfectae. Ornamentation consists of grana, coni and/or spinae, less than 1μm in height. Sculptural elements are confined to distal and equatorial hemispheres with occasional encroachment onto proximal surface.

Comparison:

Retusotriletes is comparable but differs, however, in lacking sculptured exine. Dibolisporites Richardson and Anapiculatrisporites (Potonié & Kremp) Smith & Butterworth possess sculptural elements of more than 1μm.

Apiculiretusispora fructicosa Higgs 1975

Plate 1, fig. 8

1970 Apiculiretusispora sp. A. Dolby & Neves p. 636, pl. 1, fig. 5.

1975 Apiculiretusispora fructicosa Higgs p. 395, pl. 1, figs. 23-25.

Occurrence:

Rare, Chadakoin Formation, New York State and Pennsylvania U.S.A.

Diagnosis: See Higgs 1975, p. 395.

Description:

Miospores radial trilete; amb circular to subcircular. Exine 1.5μm thick bearing ornament restricted to distal surface, over the equatorial quarter and less of the proximal face; limit of sculptured zone on proximal surface forms distinct curvaturae perfectae that mark the outer limit of the smooth contact areas. Curvaturae

may be confined entirely to the proximal face, or may be confluent with the equator along most of their length. Sculptural elements consist of discrete coni and/or bacula, pointed to rounded in profile, circular to irregular in plan; features up to 1μm wide at bases. 1-2μm high. Elements differ in density from specimen to specimen but are usually closely spaced over the distal polar region. Some specimens exhibit darkened areas adjacent to laesurae. Trilete mark distinct; laesurae straight, simple or with narrow labra normally 3μm wide, extending $\frac{3}{4}$ spore radius. Ends of rays connected with curvaturae perfectae.

Size range: 48-62μm, mean 54μm (30 specimens measured).

Remarks:

The specimens studied during the present investigations are rather smaller and possess comparatively finer ornament than those described from Southern Ireland.

Apiculiretusispora plicata (Allen) Streel 1967

Plate 2, figs. 9-11

1965 Cyclogranisporites plicatus Allen p. 695, pl. 94, figs. 6-9.

1966 ? Perotriletes sp. in McGregor & Owens pl. 5, fig. 13.

1967 Apiculiretusispora plicata (Allen) Streel p. 33, pl. 2, figs. 31,34.

Occurrence:

Present in all four of the formations investigated, abundant in the Chadakoin Formation, New York State and Pennsylvania, U.S.A.

Diagnosis: See Allen 1965, p. 695.

Description:

Miospores radial trilete; amb circular to subcircular. Exine up to 1.5μm thick, fragile, usually torn (see pl. 2, figs. 9-11),

laevigate apart from the ornament which is confined to the distal and equatorial proximal regions. Ornament consists of minute, densely distributed elements (? coni) less than 1μm, normally 0.2-0.5μm high, approaching scabrate appearance. Elements almost pointed in profile. Trilete mark distinct, laesurae straight, simple extending $\frac{3}{4}$ to full spore radius, usually accompanied by exinal folds that may obscure the suturae; ends of the laesurae connected with curvaturae that may mark the outer limit of smooth contact areas.

Size range: 35-68μm, mean 50μm (40 specimens measured).

Remarks:

Specimens of this study conform with those described by Streel (1967) and McGregor (1973). The species circumscription given above diverges slightly from that provided originally by Allen (1965). Some of the Spitsbergen specimens possess granular ornament which has not been observed in the present form.

Comparison:

Apiculiretusispora arenorugosa McGregor (1973) is too large (79-124μm) and may be distinct. McGregor (loc. cit. p. 27) justified the separation of the two species on the basis of distinct size ranges, which do not overlap. McGregor could not find many specimens of intermediate size i.e. from 75 to 80μm. Another taxon A. brandtii Streel would appear to be very close to A. plicata but differs by the usual presence of a darkened proximal area and by larger sculptural elements (up to 1μm). Apiculiretusispora sp. figured by Mortimer (1967 pl. 1, fig. N.) has larger sculptural features.

Genus PULVINISPORA Balme and Hassell emend. Ioannides M.S. 1971 in Clayton M.S. 1972

1962 PULVINISPORA Balme and Hassell 1962, p. 10

Type Species: P. depressa Balme and Hassell 1962.

Diagnosis:

From Ioannides M.S. 1971 in Clayton M.S. (1972) p. 37

"Spores radial trilete; amb circular, rounded triangular or triangular with convex or straight sides; suturae straight, may extend almost to the equatorial margin, low and narrow lips sometimes present; contact areas may be slightly depressed with their outer margin delimited by curvaturae; at the extremity of the suturae a thickening is developed; exine laevigate, infragranulate, scabrate or occasionally irregularly granulate; distal surface may bear irregular pattern of folds."

Remarks:

Ioannides emended the generic diagnosis to include triangular forms. In the emendation propounded by Evans (1970, p. 68), Pulvinispora is cogeneric with Diaphanospora Balme and Hassell (1962, p. 20). The author interprets both of these taxa as being pseudosaccate trilete miospores. In my opinion Pulvinispora is an azonate, acavate form (as is now confirmed) belonging to the infraturma RETUSOTRILETI. On the other hand Diaphanospora seems to be characterized by cavate structural organization and can well be accommodated within the infraturma MONOPSEUDOSACCATI. Consequently Pulvinispora is here treated as a coherent generic entity as by Streel (in Becker et al. 1974) and Higgs (1975).

Pulvinispora depressa Balme and Hassell 1962

Plate 2, fig. 12

1962 Pulvinispora depressa Balme and Hassell p. 11, pl. 2 figs. 1-4

Occurrence:

Abundant, Chadakoin and Cattaraugus Formations, Pennsylvania and New York State, U.S.A.

Diagnosis: See Balme and Hassell 1962, p. 11.

Description:

Miospores radial trilete; amb circular to subcircular. Exine 1.5-2.5μm thick, probably best described as scabrate; widely spaced, discrete, granular ornament may be present; grana often very sparsely distributed sometimes as few as 9 or 10 only being present with a basal diameter of 1μm to less than that. Ornament confined to distal and proximal equatorial hemispheres. Contact areas slightly to markedly depressed, semicircular in polar view, bounded by curvaturae, that may be entirely proximal or coincide through most of their length with the equator of the spore. Trilete mark distinct; laesurae straight, simple or with labra up to 3μm wide; length of laesurae $\frac{3}{4}$ spore radius, expand into radial swollen (auriculate) areas, hemispherical in outline. These terminal sutural thickenings 17.8μm in maximum width, and up to 8μm high, being wider toward equator, from where curvaturae emanate.

Size range: 40-71μm, mean 57μm (50 specimens measured).

Remarks:

The specimens described above are identical to those recorded by Balme and Hassell, from the Upper Devonian of the Canning Basin, Western Australia.

Pulvinispora quasilabrata Higgs 1975

Plate 2, fig. 13

1975 Pulvinispora quasilabrata Higgs, p. 394, pl. 1, figs. 5-6, 8.

Occurrence:

Rare, Chadakoin Formation, Bush Hill Section, Pennsylvania, U.S.A.

Diagnosis: See Higgs 1975, p. 394.

Description:

Miospores radial trilete; amb circular to roundly triangular. Exine 1-3μm thick, laevigate to scabrate apart from ornament which is confined to distal surface, and over the equatorial quarter or less of the proximal face. Ornament consists of grana almost 1μm in diameter, usually too small to be measured, normally fused to form rugulae, compression folds usually present. Trilete mark distinct; laesurae straight, simple or masked with exinal folds, rays run $\frac{3}{4}$ to full spore radius, terminating into thickened radial areas near the equator. Terminal sutural thickenings 3-7μm wide, 3-5μm high. Curvaturae emanate from radial thickenings and coincide through most of their length with the equator of the spore.

Size range: 50-67μm, mean 59μm (35 specimens measured).

Remarks and Comparison:

Specimens observed during the present investigation conform closely with Higgs' diagnosis excepting the size of ornament which is rudimentary in the material presently examined. Warg and Traverse (1973) illustrated a specimen referred to as Cyclogranisporites sp. from a Devonian-Mississippian transition zone, Central Pennsylvania; U.S.A. Though undescribed this specimen appears to resemble Aneurospora greggsii (McGregor) Streel. The present writer does not concur with

Higgs in keeping this form in synonymy with Pulvinispora quasilabrata since the miospore from Pennsylvania seems to lack radial thickenings, the characteristic of the genus Pulvinispora. Moreover, the nature of the ornament, as observed from figure, is similar to that found in Aneurospora greggsii. However, an examination of the material would be necessary to conclusively establish the nature of the miospore.

Pulvinispora sp. A. Streel (in Becker et al. 1974, pl. 16, figs. 2-3) recorded from Belgium; upper Devonian, may be conspecific with P. quasilabrata but differs in having smaller radial thickenings (1-3μm wide), and it has a smaller size range 25-33μm, (based on 4 specimens). Although undescribed, it appears to possess smooth walls.

Pulvinispora depressa Balme and Hassell 1962 differs in having larger auriculate processes at the ends of the laesurae, depressed contact areas and no compression folds.

Genus ANEUROSPORA Streel 1964

Type species: Aneurospora goensis Streel 1964

Diagnosis: See Streel 1964 p. B. 247.

Remarks:

The genus Aneurospora was diagnosed to embrace laevigate and sculptured miospores equipped with comprehensive equatorial to subequatorial crassitude formed from curvatural thickenings.

Aneurospora greggsii (McGregor) Streel in Becker et al. 1974

Plate 2, figs. 14-15; pl. 3, figs. 1-8

1964 Retusotriletes greggsii McGregor p. 8, pl. 1, figs. 1-12.

1965 Retusotriletes sp. Streel pl. 1, figs. 16-18.

1966 cf. Crassispora balteata (Playford) Sullivan in Streel p. 84, pl. 2, figs. 24-25.

1969 Retusotriletes punctatus Chibricova in Bouckaert et. al. p. 732, pl. 93, figs. 1-4.

1970 Retusotriletes greggsii McGregor, in Kaiser p. 84, pl. 16, fig. 6.

1971 Apiculiretusispora nitida Owens p. 17, pl. 3, fig. 11.

? 1973 Cyclogranisporites sp. Warg & Traverse pl. I, fig. II.

1974 Aneurospora greggsii (McGregor) Streel in Becker et al. p. 24, pl. 16, figs. 6-15.

? 1975 Apiculiretusispora granulata Owens, in Higgs pl. 1, fig. 26.

Non 1976 Apiculiretusispora granulata Owens, in Massa & Moreau-Benoit.

Occurrence:

In all four of the formations investigated; abundant in the Chadakoin Formation; New York State and Pennsylvania, U.S.A.

Diagnosis: See McGregor's 1964 description p. 8.

Description:

Miospores radial trilete; amb circular, subcircular to roundly subtriangular. Distal side normally more rounded than the proximal. Usually a part of the distal wall extends to one side as an irregular bulge, even in nearly polar compression. Exine laevigate to infrapunctate apart from ornament which is confined to entire distal surface and proximo-equatorial hemisphere; thickness of exine at equator 1.5-2μm, infrequently compressionally folded. Exine of contact areas thin. Ornament consists of minute, densely distributed coni, grana or apiculae (i.e. taper pointed, or blunt). The latter feature rarely observed. Ornamental elements 0.2 to less than 1μm high with basal width slightly less than height. Ornament equally distributed all over exine except at contact areas. Trilete mark distinct; laesurae straight, rarely sinuous, frequently accompanied by narrow slightly elevated exinal folds which taper gradually towards the equator, up to 3μm high at the proximal pole and individually up to 1.5μm wide. Rays extending $\frac{3}{4}$ or more spore radius. Ray extremities connected by arcuate thickening of the wall (curvaturae) equatorially or slightly proximally .
Arcuate thickening (abrupt change in exine thickness) differs in density from specimen to specimen from less pronounced to well defined up to 6μm wide in some cases; usually slightly wider and invaginated at the tips of the rays.

Size range: 31-67μm, mean 48μm (110 specimens measured).

Remarks:

The species has been represented in profusion from the material investigated and agrees closely with the Canadian specimens described by McGregor (1964) from the Ghost River Formation, Alberta. It differs in the nature of the ornament which, unlike the present

examples, possesses sculptural elements, in some of the specimens as long as 2 μ m.

Apiculiretusispora nitida Owens appears to be identical in terms of size and general organization. Owens (I97I, p. I7) interprets that "Representatives of this species are frequently preserved in lateral or oblique compression and commonly occur in large sporangial masses". During the current investigation identical characters have also been observed and illustrated on pl. 3, figs. 2-8.

The present author regards Cyclogranisporites sp. of Warg & Traverse (I973) to be identical with the species described above (see remarks under the species Pulvinispora quasilabrata Higgs I975).

Another taxon Apiculiretusispora granulata Owens (I97I, p. I5) appears to possess banded curvaturae in addition to the granular ornament of the distal hemisphere. Some of the specimens subsequently attributed to the Canadian species (e.g. A. granulata recorded by Higgs I975 from southeast Ireland) are tentatively placed in synonymy with the species under consideration. Although Owens (loc. cit.) himself intimated that after having determined precise enunciation of the morphological details the species could be transfered to an appropriate genus. In the writer's opinion, however, the examination of the holotype would be necessary to established conclusively the structure of the miospores.

Aneurospora greggsii var. minuta var. nov.

Plate 3, figs. II-I3

Derivation of name: Latin, minute, refering to the nature of banded curvaturae.

Holotype: Plate 3, fig. II. NY96H I48 I20I424.

Type locality: East of Smethport, road cut on rout 6, Bush Hill, Chadakoin Formation, Pennsylvania, U.S.A.

Occurrence: Rare in the Canadaway, Abundant in the Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: Trilete miospores with subcircular amb. Contact areas laevigate or scabrate. Suturae $\frac{3}{4}$ to full spore radius. The ends of the laesurae connected by poorly defined curvaturae.

Description: Miospores radial trilete; amb circular to subcircular. Exine 2-4μm thick. Contact areas laevigate or scabrate. Distal equatorial regions sculptured with small cones and grana. Exine frequently with tangential or arcuate folds folds. Trilete mark distinct; laesurae usually straight, occasionally slightly sinuous, length of rays $\frac{3}{4}$ to full spore radius, frequently accompanied by low lips, individually I-3μm wide. Laesurae terminate into poorly defined banded curvaturae which coincide with the equator through most of their length.

Size range: 4I - 75μm, mean 57μm (30 specimens measured).

Remarks and comparison:

The less densely sculptured specimens of var. minuta and those with relatively poorly defined banded curvaturae resemble the miospores assigned to Geminospora svalbardiae of Allen (1965). Intermediate forms exist however, and the range of variation is close to that observed in A. greggsii so that taxonomic separation of the two extremes seem impractical.

Aneurospora incohata (Sullivan)
Streel in Becker
et al. (1974).

Plate 3, fig. 9.

1964a Retusotriletes incohatus Sullivan p. 1251, pl. I, figs. 5-7.

1974 Aneurospora incohata (Sullivan) Streel in Becker et al. p. 24, pl. 16, fig. 4.

Occurrence:

Java, Canadaway and Chadakoin Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: See Sullivan 1964 a, p. 1251.

Description:

Miospores radial trilete; amb circular, subcircular to roundly triangular. Exine up to 2μm thick but difficult to determine, laevigate. Contact areas more or less distinct, slightly depressed, exine outside the contact areas darker and thicker. Trilete mark distinct, laesurae straight to slightly sinuous, simple or accompanied by exinal folds up to 2μm high, rays extending $\frac{3}{4}$ or more spore radius. Ray extremities seem to merge into a dark band (thickening of the wall), that may be confined entirely to the proximal surface but usually coincide with the equator; width of band variable even in the same specimen, but thicker at sutural extremities rather than interradial areas. Secondary folds infrequent, occurring as arcuate folds parallel to the equator.

Size range: 31-65μm, mean 46μm (90 specimens measured).

Remarks:

Laevigate exine and banded curvaturae, thickened at radial positions are the distinguishing features.

Comparison:

Pulvinispora depressa Balme and Hassell (1962) is a sculptured form and differs from A. incohata in possessing distinct auriculate processes at the end of each ray . Contact areas are markedly depressed.

Infraturma APICULATI (Bennie & Kidston) Potonié I956.

Genus HYSTRICOSPORITES McGregor I960

Type species: H. delectabilis McGregor I960

Diagnosis: See McGregor I960, p. 3I.

Remarks: McGregor instituted Hystricosporites to incorporate non-gulate forms only but the taxa e.g. Archaeotriletes porrectus Balme & Hassell (I962), Hystricosporites corystus Richardson (I962) and Hystricosporites coronatus Vigran (I964) have been included within the genus which show well-marked apical elevations.

Hystricosporites mitratus Allen I965

Plate 20, fig. I.

I965 Hystricosporites mitratus Allen p. 699, pl. 95, figs. 7-8.

Occurrence: Rare. Dexterville Member of the Chadakoin Formation, Pennsylvania, U.S.A.

Diagnosis: See Allen (I965), p. 699.

Size range: 70 - I30μm, mean 95μm (30 specimens measured).

Remarks and comparison: The specimens observed during the present investigation conform in all respects with Allen's diagnosis except in the nature of laesurae which are simple

in some of the specimens recorded during the current study, but grouped together in this work until enough specimens are found upon which to select criteria for separation.

Hystricosporites porcatus (Winslow) Allen

I965

Plate 20, fig. 2.

I962 Dicrospora porcata Winslow p. 52, pl. II, figs. 4-5a; pl. I2, fig. 5; pl. 22, fig. I5.

I964 Hystricosporites costatus Vigran p. I4, pl. 5, figs. 3-5.

I965 Hystricosporites porcatus (Winslow) Allen p. 699, pl. 95, figs. 4-6.

Occurrence: Rare. Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: See Winslow I962, p. 52.

Size range: 80 - I20μ m, mean 95μ m (30 specimens measured).

Remarks and comparison: The specimens described by Winslow (I962) have a greater size range (I25 - 250μ m) but the present form falls within the size range of the Spitsbergen specimens (84 - I64μ m) recorded by Allen (I965).

Identical specimrns have been reported from Canada (McGregor & Owens I966). Curry (I975) recorded H. porcatus from Frasnian of Greenland Gap Group, U.S.A. Recently Higgs (I975) recorded similar specimens from the Upper Devonian deposits of southeast Ireland.

Hystricosporites cf. porrectus (Balme & Hassell)

Allen I965

Plate 20, figs. 3-5.

? I962 Archaeotriletes porrectus Balme & Hassell p. IO, pl. 5 figs. I - 4.

? I965 Hystricosporites porrectus (Balme & Hassell) Allen p. 698. pl. 95, figs. I-3.

cf. I976 Hystricosporites porrectus (Balme & Hassell) Allen in Playford p. 34, pl. 6, figs. I8 - 23.

Occurrence: Rare. Java, Canadaway and Chadakoin Formations, New York State and Pennsylvania, U.S.A.

Size range: 70 - I30μ m, mean 89μ m (35 specimens measured).

Remarks and comparison: Among previously described species this form stands closest morphologically to Hystricosporites porrectus (Balme & Hassell) Allen in Playford (I976, p. 34) from the Upper Devonian of Canning Basin, western Australia. The present specimens differ in possessing quite a few spines borne on the equatorial and distal hemispheres, contrasting with the heavily spinose periphery in the Australian miospore population.

A Russian taxon described by Naumova, Archaeotriletes hamulus var. famenensis Naumova recorded from the Middle and Upper Devonian of the Russian Platform, bears equivocal, possibly close relationship with the present form; its morphological detail will need more precise enunciation before relationship can be assessed.

Genus GEMINOSPOA Balme emend. Owens 1971

Type Species: G. lemurata Balme 1962

Diagnosis: See Owens 1971, p. 59.

Remarks: Owens' emendation broadens the original circumscription of the taxon which now incorporates miospores sculptured with a variety of elements including grana, spinae and verrucae and also accommodates those trilete miospores which do not find their inclusion within the restricted generic concept of Archaeozonotriletes (Naumova) Allen 1965, p. 721.

Geminospora lemurata Balme 1962

Plate 3, fig. 10

1962 Geminospora lemurata Balme p. 5, pl. 1, figs. 5-10.

? 1975 Geminospora cf. lemurata Balme in Higgs pl. 6, fig. 17.

Occurrence: Rare, Chadakoin Formation, New York State, U.S.A.

Diagnosis: See Balme's 1962 description, p. 5.

Size range: Three specimens observed measuring 40, 42 and 45μ m respectively.

Remarks: A few specimens recovered during the present study agree with those described from the Carnarvon Basin, western Australia. However, the ornament appears to be coarser in the specimens from New York State, U.S.A. A single specimen illustrated by Higgs (1975) from Lower Carboniferous of Southern Ireland appears to have scabrate exine which is thickest equatorially and is hence placed, with question, in synonymy with Australian species.

Comparison: G. libyensis Massa & Moreau-Benoit 1976, though undescribed, appears to possess coarser, longer and densely distributed ornament of grana and ? bacula.

Genus VERRUCOSISPORITES (Ibrahim) Smith & Butterworth 1967

Type species: V. verrucosis (Ibrahim) Ibrahim 1933.

Diagnosis: See Smith & Butterworth 1967, p. 147.

Remarks: Smith & Butterworth (loc. cit.) restated the diagnosis of Verrucosisporites to accommodate a wider range of exine ornamentation. The taxon is characterized by having miospores predominantly sculptured with verrucae and occasional elements of rugulae, coni or bacula. Ornamentation may be reduced in contact areas.

Comparison: Convolutispora Hoffmeister, Staplin & Malloy (1955) stands closest morphologically to Verrucosisporites but the former is distinct, however, in possessing an ornament of ridges rather than verrucae.

Verrucosisporites maculosus Artuz 1957

Plate 3, fig. 14

Occurrence: Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: See Artuz 1957, p. 244.

Description: Miospores radial, trilete; amb circular to sub-circular, margin smooth to slightly undulate. Exine 2-4μm thick, uniformally thick, rim like (pseudo-rim) structure developed around the spore; miospores ornamented by discrete and coalescent verrucae,

circular to elongated in plan, rounded in profile, elements low and broad 3-7μm in diameter, 1-1.5μm in height, width of intervening spaces up to 4μm. Trilete mark obscured to perceptible; laesurae, when seen, simple, straight and hardly reach the equator of the miospores.

Size range: 49-62μm, mean 55μm (30 specimens measured).

Remarks: The specimens of the present study conform with miospores described by Artuz from Zonguldak Coalfield, Turkey (Asia).

Comparison: Verrucosisporites maculosus is distinguished from other described species of the genus by its low and relatively broad verrucae which scarcely modify the margin of the spore. V. tumulentus Clayton & Graham (1974, p. 574, pl. 1, figs. 12-14) lacks an equatorial rim surrounding the spore and is smaller (38-54μm). Comparisons can also be made with V. confertus Owens (1971, p. 19, pl. 4, figs. 3-6) but differs, however, in possessing higher (3-6μm) and wider (3-12μm) verrucae which usually modify the amb. The Canadian species is larger (73.4-108.9μm).

Verrucosisporites microtuberosus (Loose) Smith and Butterworth (1967)

Plate 4, figs.1-4

1932 Sporites microtuberosus Loose in Potonié, Ibrahim & Loose p. 450, pl. 18, fig. 33.

1934 Tuberculatisporites microtuberosus Loose p. 147.

1944 Punctatisporites microtuberosus (Loose) Schopf, Wilson and Bental p. 31.

1950 Planisporites microtuberosus (Loose) Knox p. 316, pl. 17, fig. 211.

1955 Microreticulatisporites microtuberosus (Loose) Potonié & Kremp p. 100, pl. 15, figs. 273-277.

1957 Planisporites microtuberosus (Loose) Knox; Bharadwaj p. 87, pl. 23, figs. 13, 14.

1967 Verrucosisporites microtuberosus (Loose) Smith & Butterworth p. 149, pl. 5, figs. 9-11.

Occurrence: Rare, Canadaway, Chadakoin and Cattaraugus Formations New York State and Pennsylvania, U.S.A.

Diagnosis: See Smith and Butterworth p. 150.

Description: Miospores radial trilete; amb subcircular to oval, margin smooth to crenulate. Exine almost 2μm thick usually with narrow arcuate compression folds. Exine ornamented with small closely spaced verrucae, 1-2μm in basal width, circular to polygonal, sometimes irregular in polar view, rounded to slightly pointed in profile; verrucae, normally at bases, may be more or less coalescent giving microreticulate pattern; intervening space generally 0.3μm rarely as much as 3.5μm in maximum diameter. Specimens preserved usually in off polar view. Trilete mark distinct; laesurae straight, simple extending $\frac{1}{2}$ to occasionally $\frac{3}{4}$ spore radius.

Size range: 40-73μm, mean 56μm (25 specimens measured).

Remarks: Occasional examples have been observed which are slightly smaller than those recorded elsewhere. Due to the fine nature of the ornament, the number of projecting elements around the equator could not be counted. Compressional folds on the exine have not been observed in all of the specimens studied. Despite these differences, the miospores are grouped together until enough evidence has been found to warrant their separation.

Genus ACANTHOTRILETES (Naumova) Potonié & Kremp 1954

Type species: A. ciliatus (Knox) Potonié & Kremp 1954

Diagnosis: See Potonié & Kremp 1954, p. 133.

Remarks: This category incorporates circular and triangular trilete miospores ornamented on distal, proximal and equatorial hemispheres with spinae which are at least twice as long as their basal diameter.

Comparison: The genus Acanthotriletes is differentiated from Lophotriletes (Naumova) Potonié & Kremp (I954) and Apiculatisporis Potonié & Kremp (I956) by its ornament of spinae.

Acanthotriletes horridus var. minutus var. nov.

Plate 4, figs. 5-6.

Derivation of name: Latin, minutus, little or small, referring to the small size of miospores and ornamentation elements.

Holotype: Plate 4, fig. 5, US4A I9 I244I2.

Type locality: Brick Quarries, East of Jamestown; Dexterville Member, Chadakoin Formation, New York State, U.S.A.

Occurrence: Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: Exine of miospores thin, usually torn, ornamented with spines of various shapes and size; spines straight occasionally bent, up to I3μ m in height and 5μ m in basal diameter; suturae exteng almost to the radius of spore.

Description: Miospores radial trilete; amb circular to subcircular to convexly triangular, irregular due to torn nature of exine. Exine up to 2.5μ m thick at equator, frequently thinner in centre; occasionally folded, laevigate to slightly infrapunctate apart from the ornament/spinae. The latter may reach I3μ m in height and 5μ m in basal width. Spinae taper uniformally to sharply pointed apices. Spinae often bent, non-coalescent and number thirty-five to forty around the equator. Trilete mark distinct but in a few cases indiscernible due to the

partly ruptured nature of exine; laesurae (when seen) straight or sinuous, extending almost to the equator, exine folded above the rays: folds up to 3μm high.

Size range: 45-104μm, mean 75μm (35 specimens measured).

Remarks and Comparison: The most closely comparable species described to date appears to be A. horridus Hacquebard (1957, p. 309, pl. 1, fig. 20). Apart from the size of the miospores (I24-I70μm), the length of sculptural elements (I2-33μm) also tend to be larger in the Canadian specimens. These differences are selected as suitable criteria for the erection of a new taxon at varietal level. A. hacquebardi Playford (1964, p. 20, pl. 4, figs. 1-4) differs in possessing simple and short laesurae (2/5-½ spore radius) and occasionally fused spines at the bases only for some distance along their length.

Acanthotriletes sp.

Plate 4, fig. 7

Occurrence: Chadakoin Formation, New York State and Pennsylvania, U.S.A.

Description: Miospores radial, trilete; amb subcircular, sub-triangular to oval, margin smooth (exclusive of ornament). Exinal sclulpture developed predominantly on distal and equatorial regions (reduced proximally within areas bounded by laesurae). Ornament irregular (on a given specimen) in terms of size of elements, their disposition and proportional representation: spinae, occasionally coni having circular or subcircular bases, spaced up to 7μm apart. Dimensions of sculptural features: length 1-4μm, basal diameter 0.5-2μm. Apart from projections, exine laevigate to infrapunctate, 2-3μm thick; conspicuous compression folds developed on some specimens. Trilete mark distinct; laesurae simple, occasionally accompanied by folds, suturae extending ½ to ¾ spore radius.

Size range: 48-55μm (17 specimens measured).

Remarks: The patterns of folding developed on the exine, sometimes give an impression of curvaturae. The sculptural elements observed on the present forms are preponderantly spines and therefore aptly placed in Acanthotriletes. Clearly, however, the number of specimens so far recovered is insufficient for formal taxonomic naming (i.e. species level). Partial separation of exine layers has been observed in only 20% of the specimens.

Comparison: Of previously described taxa, the Russian Frasnian species Acanthotriletes grandispinus Naumova (1953, pl. 5, fig. 77) seems to be closest morphologically to the specimens attributed here to Acanthotriletes but lacks compression folds and is of distinctly smaller size (25-35μm).

Genus DIBOLISPORITES Richardson 1965

Type species: D. eshinatus (Eisenack) Richardson 1965.

Diagnosis: See Richardson 1965, p. 568.

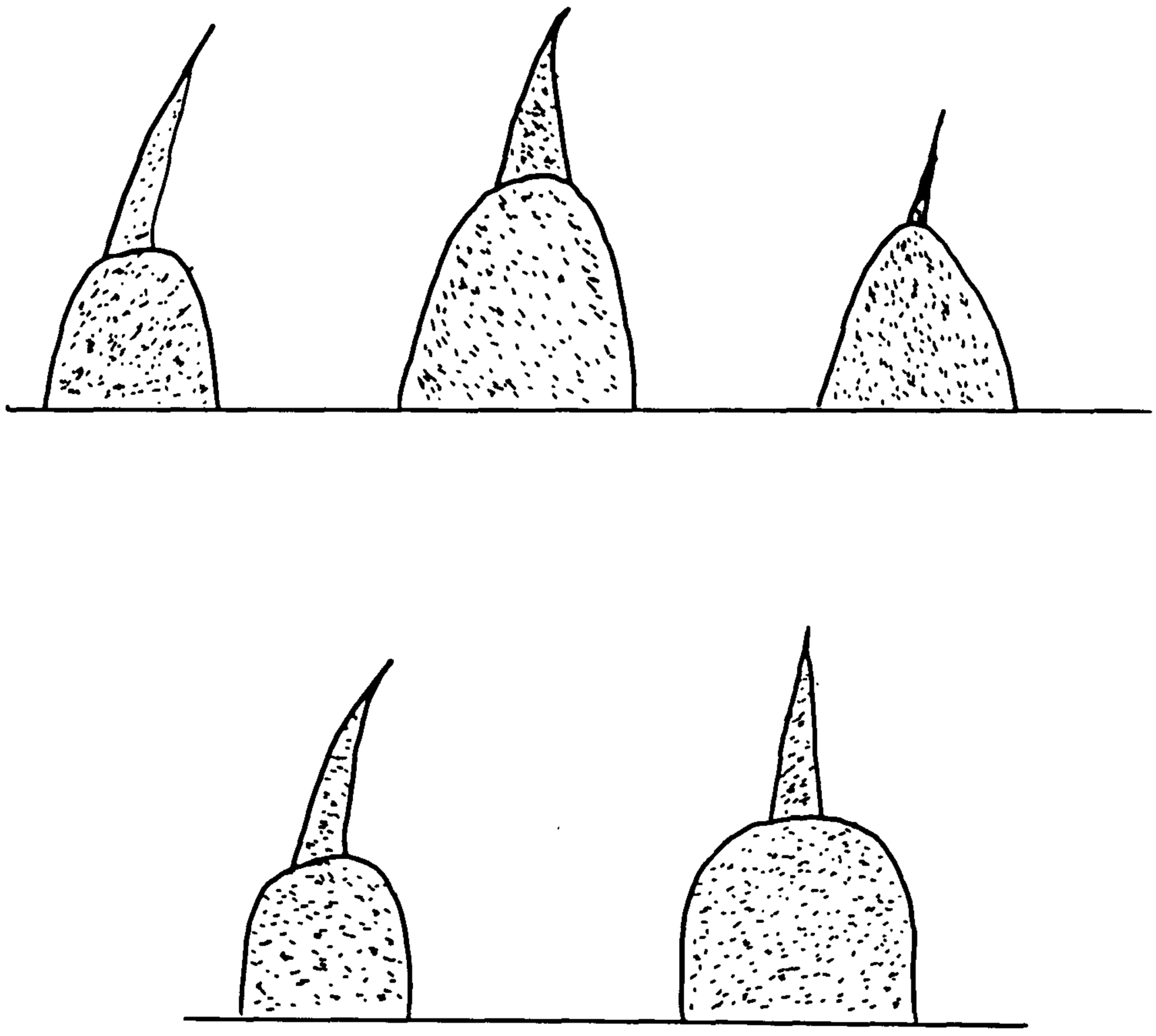
Remarks: The genus was instituted to incorporate azonate miospores ornamented with dominantly biform elements, other features such as spines, cones, pila, verrucae and rod like processes are also borne on the exine.

Comparison: Acinosporites Richardson 1965 comes closest but differs from Dibolisporites in having ornament of different types superimposed on convolute and anastomasing ridges.

Dibolisporites sp.

Plate 4, figs. 8-9

Occurrence: Chadakoin and Cattaraugus Formations, Pennsylvania, U.S.A.



Text fig. 6.1. Sculptural elements of Dibolisporites sp. Lateral views.

Description: Miospores radial trilete; amb subtriangular to oval with convex sides and rounded apices. Exine 2-3μm thick at equator, but possibly thinner in centre. Contact areas smooth or with reduced ornament. Remainder of proximal surface, distal and equatorial hemispheres conspicuously sculptured with biform elements; consisting of broad based (dome shaped) cones, superimposed on which are very fine spines; width of cones 3μm, height 1.5-3μm, basal width of spines 1μm or less, height 2-3μm; elements spacing up to 20μm; text fig. 6.I. Sculptural processes normally discrete and straight, occasionally coalesced at their bases and bent. Equatorial region fairly densely sculptured with ornament , polar region frequently sparsely ornamented; usually 14-19 elements project from the equator. Trilete mark distinct; laesura straight, extending full spore radius, sometimes exine folded above the suturae, folds up to 2-5μm raised.

Size range: 40-43μm (5 specimens measured).

Remarks: The spores occur sporadically and are not well enough preserved for precise identification at specific level. It cannot be established conclusively, at present, whether the equatorial thickening is a structural feature (zona) or merely exine thickness. The present examples are tentatively placed in Dibolisporites Richardson because azonate forms sculptured with biform elements undoubtedly correspond to Richardson's genus (see Allen 1965, p. 702).

Comparison: The studied form bears a superficial resemblance to Acanthotriletes aff. ignotus Kedo (1963, pl. 2, fig. 47). Although close comparison is impeded by the fairly generalized nature of Kedo's description and line-drawn illustration, it seems that, in lacking distinct spines surmounted by cones, A. aff. ignotus is distinct from Dibolisporites sp.

Genus RAISTRICKIA (Schopf, Wilson & Bentall) Potonié & Kremp 1954

Type species: R. grovensis Schopf in Schopf, Wilson & Bentall 1944.

Diagnosis: See Potonié & Kremp 1954, p. 134 and 1955, p. 85.

Remarks: The baculate ornament borne on proximal, distal and equatorial hemispheres of Raistrickia distinguish it from other genera. In some cases conate features also appear interspersed with baculae.

Potonié 1956 created the genus Neoraistrickia for baculate spores with markedly triangular outline. He could not provide evidence to differentiate between these forms and triangular species of the genus Raistrickia, Owens (M.S. 1963, in Clayton M.S. 1972, p. 55) therefore proposed that only species with concavely triangular amb should be assigned to Neoraistrickia. The present writer agrees with Owen's recommendation.

Raistrickia ampullacea Hacquebard 1957

Plate 4, fig. 10

1957 Raistrickia ampullacea Hacquebard p. 310, pl. 1, figs. 21-22.

1974 Raistrickia ampullacea Hacquebard; Streel in Becker et al. p. 25, pl. 17, figs. 20-21.

Occurrence: Chadakoin and Cattaraugus Formation, New York State and Pennsylvania, U.S.A.

Diagnosis: See Hacquebard's 1957 description.

Size range: 55-65.5μm (13 specimens measured).

Remark: The specimens observed during the present investigation agree significantly with those described and illustrated by Hacquebard and Streel in Becker et al.

Raistrickia baculosa Hacquebard I957

Plate 4, fig. II.

I957 Raistrickia baculosa Hacquebard p. 3IO, pl. I, figs. 23 - 24.

I964 Raistrickia baculosa Hacquebard; Playford p. 24, pl. 6, fig. 4.

Occurrence: Rare, Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: See Hacquebard's (I957) description.

Size range: 48 - 64μ m, mean 58μ m (20 specimens measured).

Remarks: Specimens recorded during the current investigation appear to be identical to miospores observed by Hacquebard except in size. The Canadian specimens vary in size from 72 to I07μ m.

Comparison: Raistrickia pinguis Playford I97I reported from the Visean of Bonapart Beds, Bonapart Gulf Basin, western Australia, is smaller 33 - 52μ m and differs in not having ornament of coni.

Raistrickia cf. clavata Hacquebard emend. Playford I964

Plate 4, fig. I2

I957 Raistrickia clavata Hacquebard p. 3IO, pl. I, fig. 25.

I957 Raistrickia pistillata Hacquebard p. 3IO, pl. 2, fig. 2.

?1964 Raistrickia clavata Hacquebard emend. Playford
p. 24, pl. 6, figs. 5-10.

Occurrence: Chadakoin Formation, Dexterville Member, Pennsylvania, U.S.A.

Diagnosis: See Hacquebard 1957, p. 310.

Description: Miospores radial trilete; amb subcircular. Exine 5μm thick; ornamented with a few sparsely distributed discrete pila and/or baculae 5-13μm high, 4-9μm broad basally, width of expanded head up to 12μm, 8 or 9 frequently project from the equator. Sculptural projections circular, rounded polygonal or elongate in basal outline; variable in lateral profile, elements expand slightly at apices to form rounded heads. Stalk more or less parallel sided, occasionally tapering slightly towards the thickened head from a wide base. Trilete mark distinct; laesurae straight, simple extending $\frac{3}{4}$ of the total spore radius.

Size range: 64μm (based on one specimen).

Remarks and Comparison: The only specimen bearing prominent and comprehensive baculate sculpture recorded during the present investigation compares closely with the morphology of the Canadian species Raistrickia clavata Hacquebard emend. Playford. Although the present form agrees with Playford's 1964 emended diagnosis it differs, however, in possessing slightly longer projections with thicker heads (on the stalk). The dimensions of elevations on Playford's specimens are as follows:- length 2.5-12μm, width of expanded heads 2.5-10μm. Owing to its extreme rarity and having a few minor differences it is not possible to delimit further taxa.

Raistrickia saetosa (Loose) Schopf, Wilson, and Bentall is probably assignable to Raistrickia cf. clavata but differs in having partly cleaved ends of the baculae (see diagnosis Potonié and Kremp 1955, p. 87 after

Loose in Potonié, Ibrahim and Loose 1932). In Verrucosisporites sp. Lanzoni and Maglorie (1969 pl. 1, figs. 7-8) sculptural elements appear to be verrucate rather than baculate. Raistrickia boleta Staplin (1960 p. 14, pl. 2, figs. 25,27) recorded from the Mississippian Golata Formation of Alberta, Canada, differs in the nature of processes which are connected to one another with muri to form an irregular reticulum.

Genus BIHARISPORITES Potonié emend. Bharadwaj & Tiwari 1970

Type species: B. spinosus (Singh) Potonié 1956.

Diagnosis: See Bharadwaj & Tiwari 1970, p. 38.

Remarks: The genus Biharisporites incorporates spores of megaspore dimensions having circular to subcircular amb. The spore surface is ornamented with coni, setae, or spinae of various shape, size, and distribution. A subcircular inner body is also present in the representatives of the taxon.

Comparison: Biharisporites is identical to Singhisporites (Potonié) Bharadwaj & Tiwari (1970) but differs in possessing distinct arcuate ridges and not having longer, fleshy, ribbon-like processes.

Biharisporites parviornatus Richardson 1965

Plate 5, figs. 1-4

1965 Biharisporites parviornatus Richardson p. 575, pl. 90, figs. 12-13 text fig. 5.

Occurrence: Chadakoin Formation Pennsylvania, U.S.A.

Diagnosis: See Richardson 1965, p. 575.

Description: Radial, trilete spores; amb subcircular to oval normally irregular. Exoexine thick, usually exhibiting arcuate folds and bearing a closely set ornament of variable size and shape consisting

of small cones, rods, tubercles and rarely spines. Elements do not exceed 2μm in height, usually discrete, occasionally fused together at their bases. Elements rounded to pointed but sometimes flat in profile circular, polygonal to irregular in plan; features absent or reduced on contact areas well-marked elsewhere. In some cases the intexine well-defined, normally folded along the equator. Trilete mark distinct; laesurae straight, simple and/or accompanied by exoexinate folds, suturae extending $\frac{1}{2}$ to $\frac{3}{4}$ spore radius, terminating (in some cases) in curvaturae perfectae.

Size range: 260-370μm, mean 310μm (41 specimens measured).

Remarks: These spores which fall within the megaspore dimensions are encountered in the material from Pennsylvania, U.S.A. These are stratigraphically confined to the lower half of the Ellicott Member. The specimens observed during the present investigations are similar to those described by Richardson (1965) from the Eday flagstone group of north east Scotland, except in the size of ornament which tends to be finer in the present case. Richardson (loc. cit.) recorded elements as being 3.5μm high, while the maximum length of the feature is 2μm in the specimens attributed here to B. parviornatus.

Biharisporites simplex Mortimer & Chaloner (1967, p. 197, pl. 27, figs. 6-8) may be identical but differs in having essentially simple laesurae. The English species is sculptured with cones exclusively.

Infraturma MURORNATI Potonié & Kremp 1954

Genus CAMPTOTRILETES (Naumova) Potonié & Kremp 1954

Type Speices: C. corrugatus (Ibrahim) Potonié & Kremp 1954.

Diagnosis: See Potonié & Kremp 1954, p. 142.

Remarks: The genus embraces trilete miospores sculptured with irregular ridges of unequal height (rudimentary cristae) or irregular, partly brancing striae.

Camptotrilletes verrucosus Butterworth & William 1958

Plate 5, fig. 5

1958 Camptotriletes verrucosus Butterworth & William p. 368, pl. 2, figs. 2-3.

Occurrence: Canadaway Formation, New York State, U.S.A.

Diagnosis: See Butterworth & William 1958, p. 369.

Description: Miospores radial, trilete; amb subcircular to rounded triangular, margin irregular to undulating. Exine up to 2.5μm thick (exclusive of ornament), sculptured with closely set ornament of irregular ridges, wart-like projections connecting ill defined verrucae. Elements up to 3μm in height and 3-5μm in basal width, evenly distributed over exine, slightly less coarse on proximal surface, and clearly discernible at equator; rounded to occasionally pointed in profile, circular to irregular in plan, separated by meandering channels. Trilete mark distinct; laesurae usually obscured by ornament; when discernible straight, simple, extending $\frac{3}{4}$ spore radius.

Size range: 50-63μm, mode 56μm (30 specimens measured).

Remarks: The species is rare when encountered and conforms with diagnosis given by Butterworth & William (1958).

Comparison: The authors differentiated C. verrucosus from C. bacculentus (Loose) Potonié & Kremp (1955, p. 104, pl. 16, figs. 287-288) on the basis of density of ornamentation which is more compact in the latter. C. superbus Neves (1961, p. 257,

pl. 31, fig. 8) has a greater size range (75-125μ m) and is ornamented by rudimentary cristae. C. corrugatus (Ibrahim) Potonié & Kremp (1955, p. 104, pl. 16, figs. 289-290) has a smaller size range (40-50μ m) and ridges tend to form a reticulate pattern.

Genus CONVOLUTISPORA Hoffmeister, Staplin & Malloy 1955

Type Species: C. florida Hoffmeister, Staplin & Malloy 1955.

Diagnosis: See Hoffmeister, Staplin & Malloy 1955, p. 384.

Remarks: Convolutispora is a trilete genus covering azonate miospores that are ornamented with overlapping ridge-like processes which do not form a well-defined reticulum.

Convolutispora definita sp. nov.

Plate 5, figs. 6-8

Derivition of name: Latin; difinitus, meaning distinct, referring to distint nature of ornamentation elements.

Holotype: Plate 5, fig. 6, NY96H 146 1068688.

Type locality: East of Smethport, road cut on rout six, Bush Hill Section, Ellicott Member, Pennsylvania, U.S.A.

Occurrence: Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: Rounded to subcircular miospores, ornamented with anastomosing, occasionally overlapping rugulae and subordinate discrete verrucae; rays $\frac{1}{2}$ to $\frac{3}{4}$ spore radius, simple and straight.

Description: Miospores radial trilete; amb circular, subcircular occasionally braodly triangular; margin smooth to slightly notched. Exine 2-3.5μ m thick (excluding sculpture), rarely with small folds. Exine distinctly rugulate on both proximal and distal hemispheres; contact areas, in a few specimens, have relatively sparse sculpture,

usually densely and equally distributed. Rugulae smooth, occasionally overlapping, irregular in form. Suboridnate discrete verrucae sometimes present. Elements circular, irregular and rarely depressed in plan, more or less rounded, conical and flat in profile, 2-3μm high, up to 5μm in width. Spacing between processes vary in width from less than 1μm to 3.5μm, lumina usually delimited. Spores frequently preserved in polar and oblique compressions. Trilete mark distinct, occasionally obscured by ornament, laesurae straight (rarely sinuous) simple extending $\frac{1}{2}$ to $\frac{3}{4}$ spore radius.

Size range: 68-85μm, mean 77μm (60 specimens measured).

Remarks: The species is profusely represented in the upper part of the Dexterville Member, Chadakoin Formation. The sculpture of corroded specimens tends to be pitted rather than smooth.

Comparison: The most closely comparable category to C. definita seems to be C. oppressa Higgs (1975, p. 397, pl. 3, figs. 3-5) which occurs in Upper Devonian-Lower Carboniferous of Hook Head, south-east Ireland. The latter is distinct, however, in having thinner exine (2μm), narrower rugulae (1-2.5μm) with frequent verrucae. The Irish form also differs in displaying lips along the laesurae. This species is also smaller.

Comparison can also be made with an Australian species described by Playford, C. balmei Playford (1971, p. 23, pl. 7, figs. 1-6). Playford's species diverges in having thinner ridges with a uniform distribution of rugulae and lumina on the spore exine and by having a greater size range (91-106μm). C. usitata Playford (1962, p. 595, pl. 82, figs. 4,7,8) possesses thicker exine (6-8μm), longer laesurae (equal to spore radius) and crowded sculptural elements.

Sabry & Neves (1971, pl. 1, figs. 2-8) illustrated a miospore referred to as Convolutispora cf mellita from the unconformable Carboniferous Basal Measures of Scotland. Though undescribed, this form appears to resemble C. difinita.

Convolutispora mellita Hoffmeister, Staplin & Malloy 1955

Plate 5, figs. 9-10

1955 Convolutispora mellita Hoffmeister, Staplin & Malloy p. 384, pl. 38, fig. 10.

1968 Convolutispora cf mellita Hoffmeister, Staplin & Malloy; in Sullivan p. 122, pl. 26, figs. 5-7.

1971 Convolutispora cf mellita Hoffmeister, Staplin & Malloy; in Clayton p. 582-3, pl. 1, fig. 8.

Occurrence: Common in the Chadakoin Formation, Pennsylvania; rare in Cattaraugus Formation, New York State, U.S.A.

Diagnosis: See Hoffmeister, Staplin & Malloy 1955, p. 384.

Description: Miospores radial trilete; amb circular to oval, margin smooth to slightly undulate. Exine sculptured with wide, low, well rounded, anastomosing ridges up to 3μm high and 7μm wide. The ridges are usually closely packed, enclosing narrow, sinuous channels and lumina. Usually ornament is reduced in height towards the proximal pole. Non-polar compressions common. Trilete mark distinct or obscured by ornament; laesurae straight, simple, extending $\frac{1}{2}$ to $\frac{3}{4}$ spore radius.

Size range: 58-84μm, mean 71μm (40 specimens measured).

Remarks and Comparison: Sullivan (1968, p. 122) stated that C. cf. mellita differs from C. mellita only in having slightly wider ridges than those quoted by Hoffmeister, Staplin & Malloy. During the course of the present investigation the population was observed exhibiting a continuous range of variation of ridge width. In

consequence C. cf. mellita Sullivan (loc. cit.) and Clayton (1971, p. 582) are considered to be synonymous with C. mellita. Butterworth & William (1958, p. 372, pl. 2, figs. 20-21) recorded a size range of C. cf. mellita ranging from 70-125μm, sculptured with rather coarser features. The Scottish spores may be distinct from those described by Hoffmeister, Staplin & Malloy (1955).

Convolutispora vermiformis Hughes & Playford 1961

Plate 6, figs. 1-3.

1957 Convolutispora flexuosa forma minor Hacquebard
p. 312, pl. 2, fig. 10.

1960 Convolutispora flexuosa forma minor Hacquebard; McGregor
p. 34, pl. 12, fig. 4.

1961 Convolutispora vermiformis Hughes & Playford
p. 30, pl. 1, figs. 2-4.

? 1965 Convolutispora vermiformis Hughes & Playford; Allen
p. 703, pl. 96, fig. 8.

Occurrence: Canadaway and Cattaraugus Formation?, New York State, U.S.A. Rare.

Diagnosis: See Hughes & Playford 1961, p. 30.

Description: Miospores radial, trilete; amb circular to sub-circular, margin smooth to undulate. Exine 2-4μm thick; ornamented with irregular, thick, elongated partly overlapping ridges of variable width and height projecting from the equator; features rounded in profile; ridges 3-8μm wide, up to 9μm high; intervening space circular, elongated to irregular, 2-18μm in diameter. Trilete mark obscured but demonstrable, laesurae straight, simple extending $\frac{3}{4}$ spore radius.

Size range: 50-63.7μm, mean 56.5μm (20 specimens measured).

Remarks and Comparison: Hughes & Playford (loc. cit.) recorded size range from 57-73μm for the specimens from the Lower Carboniferous of Spitsbergen.

The miospore ascribed to Convolutispora vermiformis Hughes & Playford in Allen 1965 is placed with question in synonymy with C. vermiformis because it is undescribed; from illustration it appears to be different by having finer ornament.

A miospore form recorded by Hoffmeister, Staplin & Malloy (1955, p. 385, pl. 38, fig. 7) is referred to Convolutispora sp. A. from the Mississippian of the Harding Formation, U.S.A. may be conspecific but dimension of ornamental features is different (smaller).

Convolutispora sp. aff. Verrucosisporites congestus Playford 1964

Plate 6, fig. 4

Occurrence: Rare, Canadaway and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Description: Miospores radial trilete; amb subcircular to circular. Exine 3-4μm thick with coalescent verrucate or low muri, feature ill-defined, elements 2-12μm wide, 1-3μm high, intervening space 1-3μm in maximum diameter. Trilete mark distinct; laesurae obscured to perceptible, simple, straight; length $\frac{1}{2}$ to $\frac{2}{3}$ of amb radius.

Size range: 50-61.2μm (5 specimens measured).

Remarks and Comparison: The form described above is a borderline case between Convolutispora vermiformis and verrucosisporites congestus Playford (1964) since the features used for separation overlap. Differs slightly from V. congestus in lacking discrete verrucae; the size range recorded by Playford ranges from 56-101μm. The form is also rather distinct from C. vermiformis Hughes & Playford (1961) in not having a well-defined reticulate pattern of ridges. V. cf. congestus Playford in Lanzoni & Maglorie (1969, pl. 1, figs. 11-12) recorded from the Sahara Algeria could be identical to the present form.

Genus EMPHANISPORITES McGregor 1961

Type Species: E. rotatus McGregor 1961.

Remarks: Emphanisporites is a well illustrated trilete genus embracing azonate miospores sculptured with well-defined radial ribs on the proximal hemisphere. Distal surface laevigate, with annulate thickening or distally sculptured with grana, coni, or verrucae. The taxon is typical of Lower to Middle Devonian rocks but occasional examples have also been observed from Upper Devonian and Lower Carboniferous sediments. The form is rare and sporadic in its occurrence in the area studied.

Comparison: Some forms of Hystricosporites also exhibit proximal radial ribs but the latter differs, however, in having prominent grapnel tipped appendages.

Emphanisporites cf. annulatus McGregor 1961

Plate 6, fig. 5

cf. 1961 Emphanisporites annulatus McGregor p. 3, pl. 1, figs. 5-6.

Occurrence: Rare, Cattaraugus Formation, New York State, U.S.A.

Diagnosis: See McGregor 1961, p. 3.

Description: Miospores radial trilete; amb subcircular. Exine 2.5μm thick. Distal surface unsculptured, proximal hemisphere ornamented with radial ribs up to 3μm wide, 2μm high at the equator; 3-6 in each interradial sector. The ribs extend all or part way toward the pole. An ill-defined concentric ring of exinal thickening (annulus) approximately 4μm wide occurs almost $\frac{1}{2}$ the way from the equator toward the distal pole. Trilete mark distinct; laesurae simple or slightly labrate, labra up to 2μm wide, rays extending full spore radius.

Size range: A single specimen seen measuring 39μm.

Remarks: This form seems to be the most closely similar to E. annulatus described by McGregor (1961, 1973). Firm attribution is not here made to McGregor's species, however, owing to the indistinct nature of the annulus on the distal hemisphere.

Emphanisporites rotatus McGregor emend. McGregor 1973

Plate, 6 figs. 6-9

1961 Emphanisporites rotatus McGregor p. 3, pl. 1, figs. 1-4.

1974 Emphanisporites sp. Clayton, Higgs, Guenn and van Gelder pl. 4, fig. 2.

? 1975 Emphanisporites sp. Turnau pl. 3, fig. 5.

Occurrence: Rare. Java, Canadaway, Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: See McGregor 1973, p. 47.

Description: Miospores radial trilete; amb subcircular to broadly triangular. Exine almost 1.5-2.5μm thick distally, on some specimens 1-2μm thicker (cingulate) in a narrow zone at the equatorial region of the distal surface. Distal face smooth; proximal side possesses in each interradial sector 4-6 radially disposed exinal thickenings (ridges) that may be 2-7μm wide and up to 2μm high at the equator. In a few cases, ridges do not extend all the way to the pole (pl. 6, fig. 9). In others these extend from the equator and usually fuse to form a thick slightly dark zone on the proximal pole. Ridges indistinct in poorly preserved specimens. Ribs normally parallel sided, occasionally tapered towards the pole. Trilete mark distinct; laesurae straight, attain the spore radius or nearly so, simple or masked with folds, up to 4μm high.

Size range: 43-70μm, mean 58μm (25 specimens measured).

Remarks: Radial ribs disposed over the proximal surface enable easy recognition of this species. The most striking specific attribute to E. rotatus is the continuous variation in its proximal sculptural pattern, ranging from distinct and well defined radial ribs to weakly developed radial ornament. Some of the specimens described here show a darker apical area, almost half the total spore diameter, which is larger than that described by McGregor (1973). Otherwise these spores are closely similar to the lectotype (McGregor 1973, pl. 6, fig. 9). In the areas studied the species is rare and sporadic in its occurrence.

A detailed synonymy listing by McGregor (1973, p. 46) is here accepted. A Polish specimen illustrated by Turnau (1975) appears to have thin radial ridges which may be the result of bad preservation.

Genus DICTYOTRILETES (Naumova) Smith & Butterworth 1967

Type Species: D. bireticulatus (Ibrahim) Potonié & Kremp 1954.

Diagnosis: See Smith & Butterworth 1967, p. 194.

Remarks: Smith & Butterworth (1967, p. 194) emended the diagnosis propounded by Potonié & Kremp to embrace only acingulate miospores which were formerly attributed to Reticulatisporites (Ibrahim) Neves (1964). The exine of Dictyotriletes is sculptured with a well defined or poorly defined reticulum which may be restricted to distal surface. Lumina regular or variable in shape, usually greater than 6μm in diameter.

Dictyotriletes cf trivialis Naumova in litt. in Kedo 1963

Plate 6, fig. 10

cf. 1963 Dictyotriletes trivialis Naumova in litt. in Kedo pl. 4, figs. 87-88.

Occurrence: Chadakoin Formation, New York State, U.S.A.

Description: Miospores radial, trilete; amb subcircular, margin irregular. Exine corroded, muri present, which form an imperfect reticulum up to 4μm thick and project at the margin. Intervening space (lumina) polygonal to irregular, number of muri difficult to determine but size appears to be up to 15μm in diameter. Muri rounded in profile. Trilete mark not visible.

Size range: A single specimen recorded measuring 80μm.

Remarks: The only example observed during the present investigation superficially resembles that illustrated by Kedo (1963, pl. 4, fig. 88). Despite its morphological simplicity the form described above is not directly assigned to the Russian species on account of the corroded nature of its exine and absence of trilete mark. Probably, if enough specimens are examined, these factors do not hinder or prevent identification.

Dictyotriletes sp.

Plate 6, fig. 11

Occurrence: Rare, Chadakoin and Cattaraugus Formations; New York State, U.S.A.

Description: Miospores radial trilete, amb subcircular to broadly triangular. Exine 2-4μm thick at the equator. Proximal surface laevigate, distal hemisphere reticulate. Lumina of reticulum 6-18μm in greatest diameter, usually polygonal in outline, may be somewhat irregular; lumina commonly (but not always)

slightly larger toward the distal pole. Number of lumina per specimen up to seventeen. Muri of reticulum 2-4μm thick, 3-6μm high, normally project at the amb; rounded to pointed in profile, distinct and strongly developed. Laesurae simple, straight extending ¾ to almost spore radius, commonly not detectable.

Size range: 51-76.5μm, mean 64μm (20 specimens measured).

Remarks and Comparison: The specimens were observed which at a first approximation are identical to D. emsiensis (Allen) McGregor 1973, p. 42, pl. 5, fig. 15). However, careful examination reveals the absence of grana or small verrucae on the proximal surface. The muri, in Spitsbergen and Canadian specimens, are commonly widened or papillate at their junctions. Another taxon described by McGregor, D. subgranifer McGregor (1973, p. 43, pl. 5, figs. 16,18-20) would appear to be very close to the present form but differs in having narrower and lower muri that are serrated along the upper edge and in Canadian specimens the proximal surface is granulate.

Subturma ZONOTRILETES Waltz 1935

Infraturma CINGULATI Potonié & Klaus 1954

Genus KNOXISPORITES Potonié & Kremp emend. Neves 1961

Type Species: K. hageni Potonié & Kremp 1954.

Diagnosis: See Neves 1961, p. 264.

Remarks: Neves 1961 formulated the emended diagnosis of the genus to include miospores having a cingulum of uniform thickness which tapers slightly towards the equator and the distal hemisphere, in this category, is sculptured with radial or concentric thickened bars.

Comparison: Reticulatisporites (Ibrahim) Neves 1964 differs in having a differentiated cingulum.

Knoxisporites literatus (Waltz) Playford 1963

Plate 7, figs. 1-2

1938 Zonotriletes literatus Waltz in Luber & Waltz
p. 18, pl. 2, fig. 21; pl. A. fig. 11.

1956 Eurozonotriletes literatus (Waltz) Ishchenko
pp. 52-53, pl. 9, fig. 108.

1956 Anulatisporites literatus (Waltz) Potonie & Kremp p. 111.

1957 Cincturasporites literatus (Waltz) Hacquebard & Barss
pp. 23-24, pl. 3, figs. 2-5.

1962 Labiadensis literatus (Waltz in Hacquebard & Barss)
Bharadwaj & Venkatachala
p. 38, pl. 8, figs. 128-130.

1963 Archaeozonotriletes literatus (Waltz) Kedo
pl. 8, figs. 188-190.

1963 Knoxisporites literatus (Waltz) Playford p. 634, pl. 90,
figs. 7-8.

1970 Archaeozonotriletes literatus (Waltz) '?Naumova' in McGregor
pl. 21, fig. 13.

? 1970 Knoxisporites cf literatus (Waltz) Playford in Combaz &
Streel p. 233, pl. 3, fig. 12.

Occurrence: Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: See Playford 1963, p. 634.

Description: Miospores radial trilete; amb subcircular to subtriangular; periphery smooth or may show gentle undulations. Cingulum 5-10μm wide (normally up to 7μm), well defined, uniform in thickness, width usually consistant on same specimen. Distal surface conspicuously sculptured with smooth and almost rounded muri which occur over the entire distal surface; muri anastomose and frequently joined to cingulum by a variable number of radiating thickened bars, width of muri up to 10μm. Proximal surface laevigate. Trilete mark distinct; laesurae straight, length equal to or slightly less than inner margin of the cingulum;

suturae accompanied by broad, smooth lips, 4-12μm wide.

Size range: 54-78μm, mean 66μm (35 specimens measured).

Remarks and Comparison: The specimens observed during the present investigation comply with Playford's description except in the width of cingulum which is wider (8-19μm) in the Spitsbergen specimens.

K. hederatus (Ishchenko) Playford (1963), originally recorded from the western extension of the Donetz Basin in sediments of Tournaisian - Lower Viséan age, is structurally identical but differs, however, in having simple laesurae.

Identical forms have widely been reported from Famennian to Viséan throughout the world. Recently Allen (in Gayer et al. 1973) illustrated two specimens of K. literatus from the Lower Tournaisian of Taff Gorge, Glamorgan. In the writer's opinion a specimen in Plate 14, fig. L seems best excluded from the Russian species because its distal ornament is not well delineated. The specimen can well be accommodated within the circumscription of K. pristinus Sullivan 1968.

Knoxisporites pristinus Sullivan 1968

Plate 7, figs. 3-4

1968 Knoxisporites pristinus Sullivan p. 123, pl. 27, figs. 1-5.

Occurrence: Chadakoin and Cattaraugus Formation, New York State and Pennsylvania, U.S.A.

Diagnosis: See Sullivan 1968, p. 123.

Description: Miospores radial, trilete; amb subcircular, sub-triangular with convex interradial margins and rounded apices; periphery smooth to almost undulate. Cingulum distinct to ill-defined, uniform in thickness but in width may be either consistant

or somewhat variable on same specimens. Distal surface ornamented with coarse irregular thickenings that are variable in shape and usually vaguely defined. The muri may, in places, be branched and infrequently connected to form a reticulum imperfectum. Width of thickened bands difficult to determine due to poor preservation. Exine otherwise laevigate, proximal side smooth. Specimens occasionally preserved in good proximodistal orientation. Trilete mark distinct, laesurae extending almost $\frac{3}{4}$ spore radius; accompanied by lips, up to 6μm wide on either sides.

Size range: 53-76.5μm, mean 62μm (50 specimens measured).

Remarks: The specimens incorporated in the foregoing description are more frequently distributed in the area studied than the specimens attributed to Knoxisporites literatus. The present representatives are somewhat smaller than those described by Sullivan 1968 (62-103μm).

Comparison: Morphologically and dimensionally K. pristinus Sullivan is more or less identical to K. literatus (Waltz) Playford (which Sullivan did not in fact record). Sullivan (1968, p. 123) erected a new species on the seemingly slight grounds that it exhibits non-polar compression and ill defined distal thickenings. During the present study, forms assignable to these two species have been recovered and the fact that a few morphographic intermediates were found enables me to uphold Sullivan's speciation. It can also be suggested that forms with an almost irregular amb (due to non-polar orientation), vaguely defined distal muri and with relatively thin contact areas should be confined to K. pristinus Sullivan.

A form assigned to K. literatus by Allen in Gayer et all. (1973, pl. 14, fig. I) can easily be accommodated within the circumscription of K. pristinus Sullivan.

Knoxisporites sp. aff. Reticulatisporites crassus Winslow 1962

Plate 7, fig. 5

Occurrence: Canadaway Formation, Northeast Shale Member, New York State, U.S.A.

Description: Miospores radial trilete; amb oval or irregular due to differentiated cingulum; periphery undulate. Cingulum up to 7μm wide. Proximal surface laevigate. Distal hemisphere conspicuously sculptured with coarse irregular thickenings that may be sharply defined and more or less rounded in profile. Muri (thickenings) occur over entire distal surface and anastomose enclosing polygonal or irregular lumina up to 8μm wide. Muri frequently join the cingulum projecting at equator. Muri up to 5μm wide. Trilete mark distinct; laesurae straight, bordered by lips 5μm wide on either side ; one ray cleaved at its tip, suturae approaching inner margin of the cingulum or nearly so.

Size range: Two specimens seen measuring 76.5 and 81.6μm respectively.

Remarks and Comparison: The morphology of above described form appears to be distinct from previously described forms attributable to Knoxisporites. K. cinctus (Waltz) Butterworth & William (1958 p. 370, pl. 2, figs. 11-13) somewhat resembles K. sp. aff. R. crassus from which it can be distingusihed as it possesses three pairs of proximal muri, each enclosing a laesura.

A positive assignment to Reticulatisporites crassus Winslow (1962 p. 58, pl. 14, figs. 8-10a and Pl. 22, fig. 23) must be withheld since the differentiated cingulum and the nature of the distal ornament are common in the forms from both areas. A firm attribution is not here made to Winslow's species, however, owing to the presence of muri along rays. Winslow's specimens have a greater size range (94-147μm).

Genus LOPHOZONOTRILETES Naumova 1953

Type Species: L. lebedianensis Naumova 1953.

Diagnosis: See Naumova 1953, p. 25,50 (French transl.); Potonié 1958, p. 27, or Potonié 1966, p. 87.

Remarks: The miospores attributed to this genus are acavate, cingulate, sculptured with verrucate and/or conate ornament .

Richardson & Ioannides (1953, p. 280) remarked that the holotype of Lophozonotriletes lebedianensis Naumova selected by Potonié (1958, pl. 2, fig. 21) does not possess a distinctive cingulum while in the customary sense this feature is well defined. In consequence the type species is not a true representative of the taxon. Playford (1976, p. 28) also seems to be unsatisfied with the present status of the genus. In the present work the miospores are attributed to the above genus on the ground that they contain a well-developed cingulum.

Lophozonotriletes curvatus in Naumova 1953

Plate 7, figs. 6-7

1953 Lophozonotriletes curvatus in Naumova p. 89, (French trans.) pl. 15, figs. 43-45 and pl. 19, figs. 25-30.

Occurrence: Rare. Chadakoin Formation, Pennsylvania, U.S.A.

Diagnosis: See Naumova 1953 (French translation) p. 89.

Description: Miospores radial, trilete; amb subcircular to subtriangular with almost straight to convex sides and rounded apices. Equatorial thickening (cingulum) of comparable density to the remainder of exine with uniform or somewhat variable width on same specimen, cingulum almost well defined, 3-4 µm wide. Distal and equatorial hemispheres sculptured with discrete to coalescent coni and irregular elements of variable height. Projections taper

gently toward the apex; in plan view, subcircular to elongate to irregular; in profile rounded to pointed. Processes 3-7μm in basal width, up to 6μm high. Ornament densely to sparsely set. Remainder of exine laevigate or with rare elements. Trilete mark distinct; laesurae straight, extending for ¾ of radius, rays simple or occasionally accompanied by narrow labra up to 3μm high.

Size range: 39-55μm, mean 47μm (25 specimens measured).

Remarks and Comparison: Specimens are sparingly represented and conform with the Russian illustrations except in the nature of the laesurae which are rather labrate in some of the examples observed during the present investigation.

Recombination of the species with Converrucosisporites Potonié & Krepm (1954) suggested by Turnau (1975, p. 510) is rather doubtful. Some of the specimens illustrated by Naumova (1953, pl. 15, fig. 45; pl. 19, fig. 27) and Turnau (loc. cit. pl. 2, fig. 1) are not distinctly triangular, a characteristic which is a significant factor in assigning the species to the genus Converrucosisporites. In terms of ornament, which seems to be biform, the Polish specimens may belong to a different species.

In addition to the Russian Platform identical specimens have also been recorded from the Pripyat Depression (Kedo 1957, 1963).

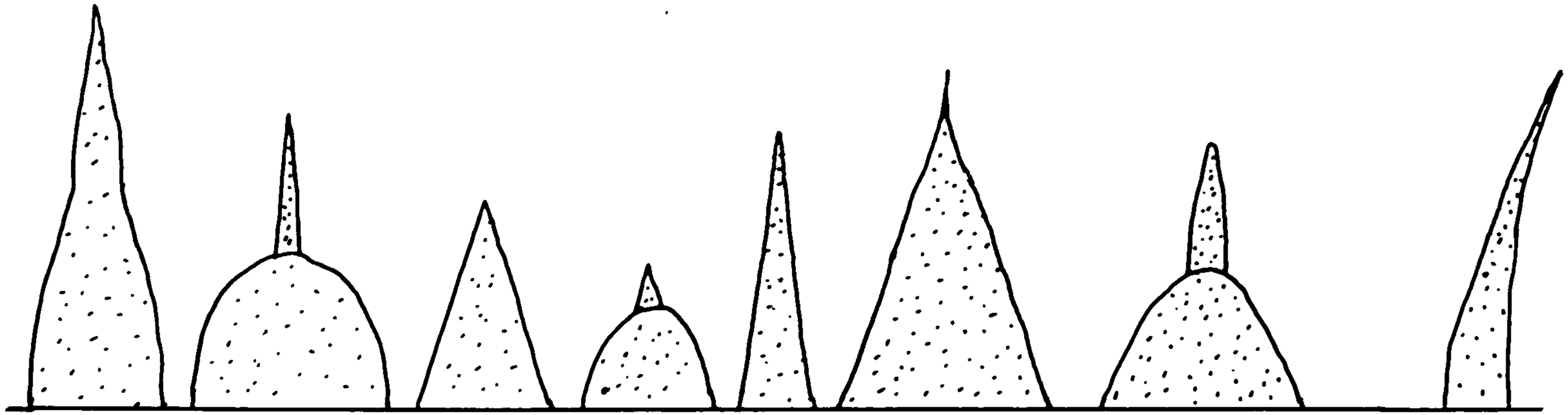
Genus VALLATISPORITES

(Hacquebard) 1957 Sullivan 1964b

Type Species: V. vallatus Hacquebard 1957.

Diagnisis: See Sullivan 1964b, p. 370.

Remarks: Ori inally described by Hacquebard, the genus has been modified by Sullivan (1964b), Staplin & Jansonius (1964, p. 111) and Dolby (Ph. D. Thesis 1970, p. 108). In present work Vallatisporites is used in the sense implied by Sullivan (1964b, p. 370) i.e. for



Text fig. 6.2. Sculptural elements of Vallatisporites vallatus var. hystricosus (Winslow) Clayton et al.

trilete zonate miospores that have equatorial border internally vacuolate, cuniculus located at the equator of the spore cavity, and distal exoexine possessing cones, verrucae and spinae.

Vallatisporites vallatus var. hystricosus (Winslow) Clayton et al. I977

Plate 7, figs. 8-II, I3.

I957a Hymenozonotriletes pusillites Kedo p. 22, fig. I.

I962 Cirratriradites hystricosus Winslow p. 4I, pl. I8, fig. 5.

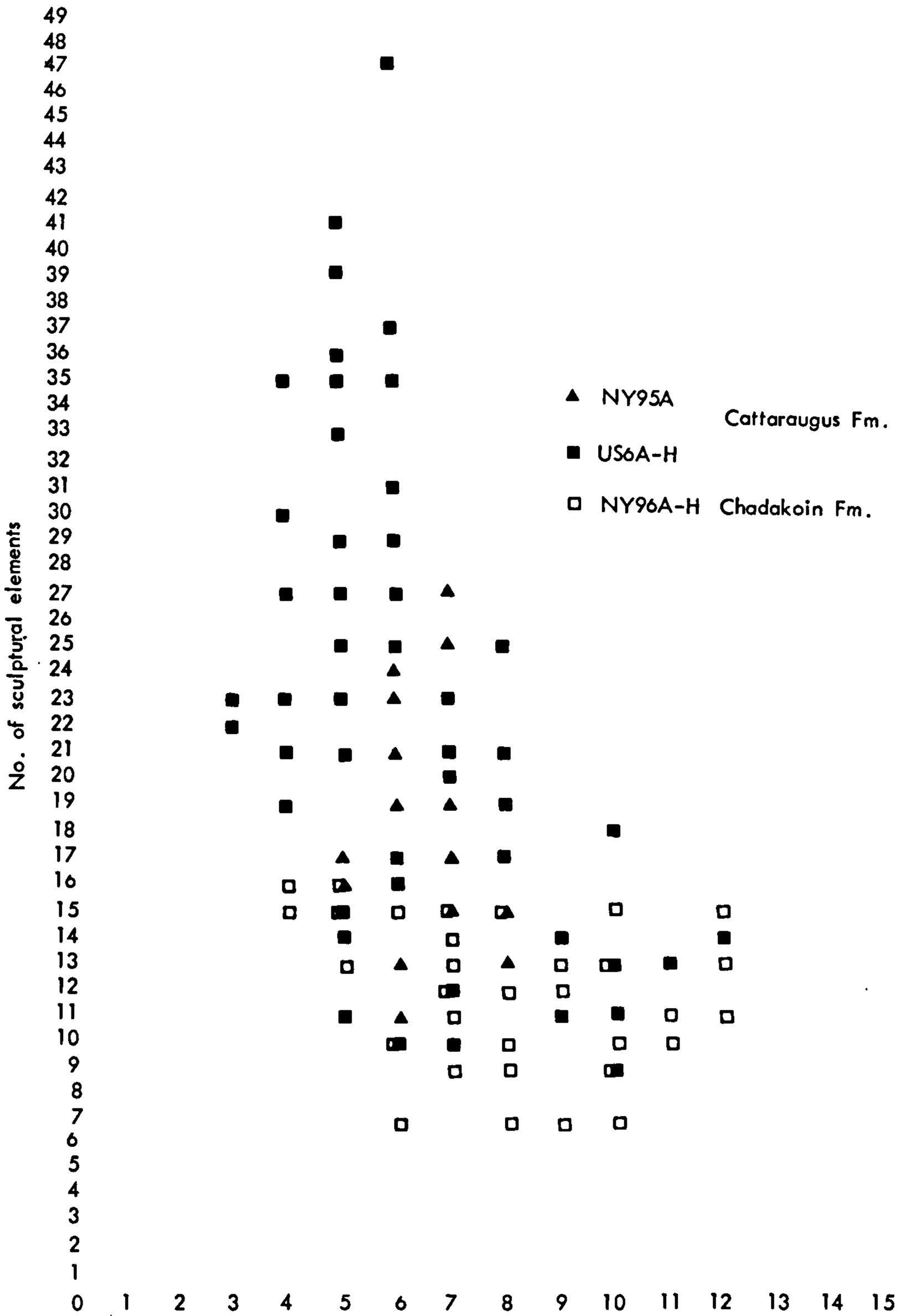
I970 Vallatisporites pusillites (Kedo) Dolby & Neves p. 639, pl. 2, figs. I-4.

Occurrence: Frequently observed in the Cattaraugus and upper part of the Chadakoin Formations, New York State and Pennsylvania, U.S.A.

Description: Miospores radial trilete; amb subtriangular with convex sides and rounded apices, ranging from subtriangular to subcircular. Exine double layered; intexine laevigate, attached over the distal and proximal surfaces, comprising 75 to 90% of the total spore diameter; exoexine smooth to infrapunctate, equatorial part of the proximal surface and whole of distal surface ornamented by spines, biform elements and cones, I2μm in maximum height and basal diameter ranging from I-5μm (see text fig. 6.2.). Elements stout and discrete, rarely bent. Equatorial flange (distance from intexine to the equatorial margin) as wide as I0.2μm. Along the equator of the intexine a cuniculus commonly developed, whilst the cingulum contains oval, circular to elliptical vacuoles, I.5-8μm long in the radial position. Trilete mark normally distinct; laesurae straight to sinuous and do not extend beyond the inner margin of the cingulum; rays usually accompanied by folds, up to 4μm high.

Size range: Exoexine 40-70μm, mean 55μm; intexine 30-55μm, mean 42μm (I05 specimens measured).

Remarks and Comparison: Due to the restricted vertical range in the present study, the first appearance of V. vallatus var. hystricosus is used to define the base of the HL Assemblage Zone.



Text fig. 6.3. Distribution of sculptural elements in V. vallatus var. hystricosus (Winslow) Clayton.

It has been observed during the present investigation that the specimens examined from the higher part of the sequences (Cattaraugus Formation) are densely sculptured when compared with the older, Chadakoin Formation. It is evident from text fig. 6.3. that specimens having sculptural elements more than sixteen have not been found occurring in the Chadakoin Formation; whilst up to 47 ornamentation elements have been observed on the specimens from the younger, Cattaraugus Formation.

It is of interest to note that the size of the sculptural elements of Cirratriradites hystricosus of Winslow recorded from the Bedford, Cuyahoga and Logan Formation, Ohio, range in length from 2 to 5.2 μm. The identical specimens have also been observed from New York State and Pennsylvania and the maximum size of the sculptural elements have been recorded up to I2 μm.

Vallatisporites vallatus var. major (Kedo) comb. nov.

Plate 7, fig. I2.

I963 Hymenozonotriletes pusillites var. major Kedo pl. 6, fig. I43.

Occurrence: Rare, Cattaraugus Formation, New York State, U.S.A.

Size range: Two specimens encountered measuring 85 and 90 μm respectively.

Remarks: The specimens observed during this study comply with the description of V. vallatus var. hystricosus excepting the size range, which tends to be greater in the present form. V. vallatus var. major has a restricted vertical range when compared with its mother species.

Subturma ZONOTRILETES Waltz I955

Infraturma CRASSITI Bharadwaj & Venkatachala I96I

Genus AMBITISPORITES Hoffmeister I959

Type species: A. avitus Hoffmeister I959

Diagnosis: See Hoffmeister I959, p. 33I.

Remarks and Comparison: The taxon Ambitisporites was founded by Hoffmeister from Libyan Lower Silurian sediments and embraces laevigate, trilete miospores coupled with an equatorial crassitude. The category could be placed in synonymy with Stenozonotriletes Hacquebard (1957). Richardson (1969), however, indicated that the interest in Hoffmeister's spores is that they are from "high Lower Silurian" strata. The genus is treated here as a coherent generic entity.

Ambitisporites cf. avitus Hoffmeister 1959

Plate 8, fig. 1-2

cf. 1959 Ambitisporites avitus Hoffmeister p. 332, pl. 1, figs. 1-8.

Occurrence: Rare. Canadaway, Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Description: Miospores radial trilete; amb subtriangular with almost straight to convex interradial margins and rounded to slightly extended apices. Exine thickness along equator (crassitude) 2-5μm. Contact between equatorial thickening and rest of exine distinct. Exine over contact areas thin and laevigate to slightly infrapunctate. Trilete mark distinct; laesurae usually accompanied by folds up to 7μm high, straight to slightly sinuous, approaching the inner margin of the thickened equatorial zone.

Size range: 38-56μm, mean 47μm (20 specimens measured).

Remarks: The specimens observed during the present investigation are tentatively left in the species Ambitisporites avitus Hoffmeister 1959 because of the identical nature of crassitude. A difference such as folds along laesurae is not regarded, at present, sufficient ground for separation. They are grouped together for convenience, until enough specimens are found upon which to select criteria for separation. A specimen illustrated by Richardson and Lister (1969, pl. 40, fig. 2) is most probably assignable to the present form. A more or less identical specimen has also been

reported by Cramer (1966, pl. 2, fig. 34) from some Silurian-Devonian rocks of northwest Spain.

Genus STREELISPORA Richardson & Lister 1969

Type Species: S. newportensis (Chaloner & Streel) Richardson & Lister.

Diagnosis: See Richardson & Lister 1969, p. 230.

Remarks and Comparison: The diagnosis of Streelispora propounded by Richardson & Lister covers crassitudinous trilete miospores, ornamented with granulate, conate, spinose and/or biform elements; proximal surface laevigate or with interradial papillae. The genus is distinct from Aneurospora Streel 1964 since the latter does not possess an equatorial thickening.

Streelispora catinata (Higgs) comb. nov.

Plate 8, figs. 3-5

1975 Crassispora catinata Higgs p. 396, pl. 2, figs. 1-3.

Occurrence: Almost in all the samples studied.

Diagnosis: See Higgs 1975, p. 396.

Description: Miospores radial trilete; amb subcircular, subtriangular to oval. Proximal surface laevigate, contact areas bounded by distinct to barely distinguishable crassitude, up to 5μm wide, width differs from place to place even on a single specimen. Distal and equitorial hemispheres covered with spinae, coni and grana; elements with rounded to pointed apices, up to 1μm in width and 2μm in height, sometimes characteristically coalesced to form irregular ridges. Specimens rarely thrown into fine folds of irregular orientation. Trilete mark distinct, laesurae straight, extending $\frac{3}{4}$ to full spore radius, terminating in curvaturae imperfectae; rays usually masked with folds 1-2.5μm in height and width.

Size range: 40–65μ m, mean 52μ m (95 specimens measured).

Remarks and Comparison: The specimens here assigned to Streelispora (Crassispora) catinata comb. nov. are closely comparable to the specimens from the Upper Devonian of southwest Ireland illustrated by Higgs (1975), although the structural interpretations placed on the present specimens differ considerably from those made by Higgs in the original description of the species. Although Higgs(1975)made no specific reference to equatorial thickening (crassitude), it seems probable from interpretation of (at least the one) illustrated specimen (Higgs loc. cit. pl. 2, fig. 2) that such a feature (structure) is in fact present. Therefore, allocation of the species to Streelispora is preferred. Both the genera Crassispora and Streelispora are crassitudinous but inclusion of the present form within Streelispora is justified since Crassipora lacks granulate ornament. Apical paillae, in the latter are probably constant feature (see Sullivan 1964b, pl. 375).

Streelispora distincta sp. nov.

Plate 8, figs. 6–11

Derivation of name: Latin, distinctus, meaning separate, referring to the discrete nature of ornament.

Holotype: Plate 8, figs. 6–7 US6H 319 1195581.

Type locality: Pope Hollow Section; along boundary between Carroll and South Vally Townships, Jamestown quadrangle, New York State.

Occurrence: Canadaway, Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: Miospores with distinct equatorial crassitude of uniform width, distally and equatorially ornamented with coni and grana, suturae terminating in curvaturae perfectae.

Description: Miospores radial trilete; amb subtriangular to rounded triangular, sides distinctively convex. Exine 0.5-1.5μm thick distally, contact areas highly distinctive and smooth. Well delineated equatorial crassitude 2-4μm wide with uniform width. The examples bear a loosely set ornament of grana, coni and/or spinae which are confined to the equatorial margin and distal hemisphere; ornamentation elements 0.5-2μm high, up to 1.5μm in diameter, circular in plan, pointed or rounded in profile. Spores usually compressed in polar views. Trilete mark distinct; lassurae straight, simple or accompanied by lips 0.5-1.5μm wide, length of rays $\frac{3}{4}$ to full spore radius, terminating in curvaturae perfectae, which coincide through most or all of their length with the equator of the spore.

Size range: 35-60μm, mean 45μm (60 specimens measured).

Remarks: On the grounds of characters described above, the species seems to be best left in Streelispora.

Comparison: S. catinata (Higgs) comb. nov. somewhat resembles S. distincta sp. nov. from which it can be differentiated by being populated by vaguely defined equatorial thickening and by having coalescent ornamentation elements. S. newportensis (Chaloner & Streel) Richardson & Lister bears three interradial papillae and in S. granulata Richardson & Lister crassitude is thicker in the interradial areas than in the radial region.

Genus SYNORISPORITES Richardson & Lister 1969

Type Species: S. downtonensis Richardson & Lister.

Diagnosis: See Richardson & Lister 1969, p. 232.

Remarks: Synorisporites Richardson & Lister 1969 is a trilete miospore genus equipped with equatorial crassitude and curvaturae perfectae. Distal surface comprehensively ornamented with verrucate and/or murornate elements.

Comparison: Synorisporites is distinguishable fairly readily from Streelispora as it has sculptural elements of verrucae and muri rather than grana, coni and spinae. Ambitisporites Hoffmeister (1959) is a laevigate crassitudinous taxon.

Synorisporites flexuosus comb. nov.
(Jusch. in Kedo & Golubtsov)
Plate 9, fig. 1-9

Non 1953 Hymenozonotriletes famenensis Naumova p. 77 (French transl.) pl. 17, fig. 17.

Non 1953 Hymenozonotriletes mirandus Naumova p. 36 (French transl.) pl. 18, fig. 34.

Non 1963 Hymenozonotriletes famenensis Kedo pl. 5, fig. 109.

1966 ? Perotriletes sp. McGregor & Owens, pl. 28, fig. 25.

1967 Hymenozonotriletes famenensis Kedo; Neves & Dolby pl. 2, fig. 3.

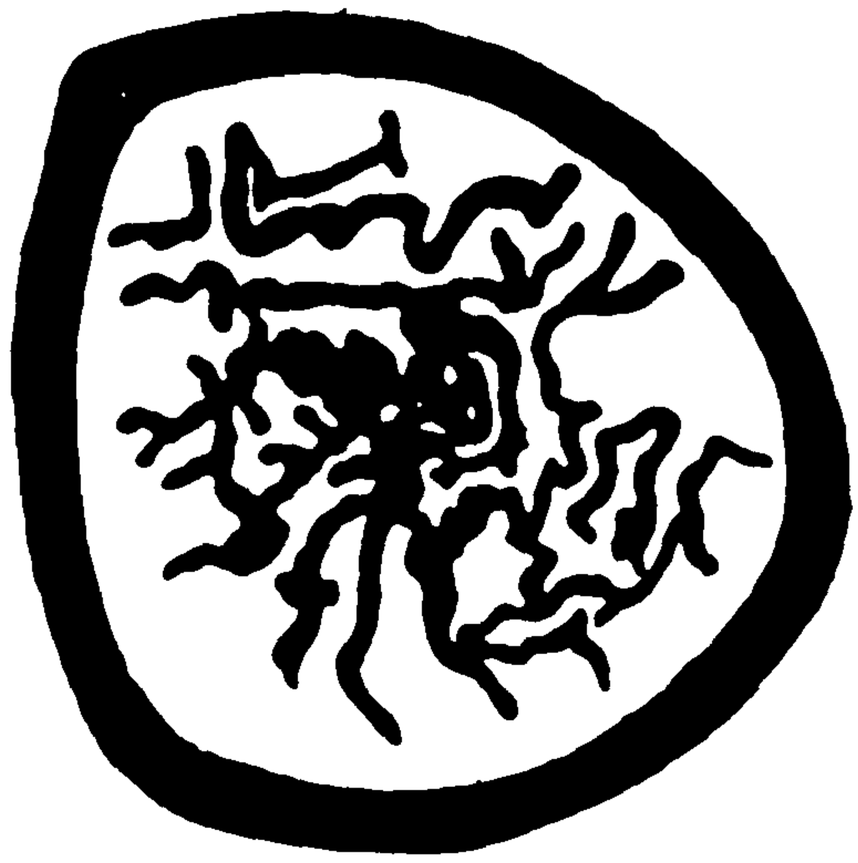
1970 Rugospora miranda (Naumova) Dolby M.S. p. 103, pl. 9, figs. 8-10.

1971 Trachytriletes flexuosus Jusch. in Kedo & Golubtsov pl. 5, fig. 1.

1974 Rugospora flexuosus (Jusch. in Kedo & Golubtsov) Streel in Becker et. al. pl. 21, figs. 8-11.

Occurrence: Abundant. Canadaway (N.E. Shale Member) Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Description: Miospores radial trilete; amb triangular to sub-triangular with rounded apices; often two apices rounded and the third subangular; margin smooth. Exine 2-3μm thick distally (exclusive of ornament). Proximal surface smooth, thin; contact areas well defined, bounded by curvaturae perfectae; occasionally one is smaller than the other two. Crassitude prominent, laevigate, rounded, 2-6μm wide with more or less uniform width. Distal surface sculptured with irregular muri confined within the



Text fig. 6.4. Diagrammatic sketch illustrating the distal ornament in Synorisporites flexuosus (Jusch) comb. nov.

crassitude, 1-4μm wide, 1-2μm high, length difficult to determine due to meandering nature (approximately 45μm in maximum length). Muri concentrated on distal polar region with diverging tendency towards equator, rarely closely packed, usually well spaced, angular in plan. Lumina 1-5μm wide. Polar compressions common. Trilete mark distinct; laesurae straight, extending $\frac{3}{4}$ to full spore radius, simple or associated with lips or folds normally decreasing from 2μm in total width towards the equator. Suturae may terminate in curvaturae perfectae, confluent with crassitude along their total length.

Size range: 43.3-67μm, mean 53μm (200 specimens measured).

Remarks and Comparison: The presence of a distinctive equatorial crassitude together with well defined distal murornate ornament studied under light and scanning electron microscope (SEM), renders appropriate the assignment of this species to the genus Synorisporites Richardson & Lister. The arrangement of muri (confined within the crassitude) on the distal region is variable but gradational from specimen to specimen and does not form a basis for further speciation. Wide geographical distribution, but the restricted vertical range of S. flexuosus (Jusch.) comb. nov. contribute to its usefulness as an index fossil. In the present study its first appearance is used to define the base of the S. flexuosus - A. varia Assemblage Zone.

Hymenozonotriletes famenensis in Neves & Dolby subsequently recovered from British Isles by Dolby (1970, pl. 19, fig. 8); Utting & Neves (1970, pl. 27, fig. 9); Allen in Gayer et al (1973, pl. 15, fig. 5) and specimens illustrated from Canada by McGregor (1970, pl. 23, fig. 4) and from Pennsylvania by Warg & Traverse (1973 pl. 1, fig. 4) are almost certainly junior synonyms of S. flexuosus (Jusch.) comb. nov. H. famenensis Kedo in Clayton et al. (1974) is

probably a different form.

Synorisporites richardsonii sp. nov.

Plate 9, figs. 10-12

Derivation of name: The species is named after Dr. J.B. Richardson, in recognition of his research on Silurian-Devonian miospores with equatorial crassitude (Richardson & Lister 1969, Richardson & Ioannides 1973).

Holotype: Plate 9, figs. 10-11 NY95C 37 119663.

Type Locality: Lewis Run, Hanley Quarries, Cattaraugus Formation, Pennsylvania, U.S.A.

Occurrence: Rare. Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: Miospores with distinct equatorial thickening; ornament of verrucae and rare coni disposed over the entire distal and equatorial hemispheres; laesurae straight or barely sinuous, simple, occasionally accompanied by lips or folds.

Description: Miospores radial trilete; amb subtriangular with convex sides and rounded apices, ranging from subtriangular to subcircular. Exine proximally laevigate, thin, occasionally tending to break down. Contact areas distinct and delimited by curvaturae perfectae, forming an equatorial thickening of 3.5-6 μm. Distal and equatorial hemispheres sculptured with verrucae and/or rare coni, 1.5-2 m high, 1-3 μm wide at their base. In plan view they are circular, subcircular or irregular; in profile rounded, almost pointed or with flattened apices, ornamentation elements densely packed at the equatorial margin, but widely spaced on the distal hemisphere. Specimens occasionally occur with compression folds, whilst proximo-distal orientation frequent. Trilete mark distinct; laesurae straight

or slightly sinuous, extending between $\frac{3}{4}$ of radius and almost to spore margin, simple or accompanied by folds or lips up to 4μ m high.

Size range: 38-44μ m, mean 41μ m (40 specimens measured).

Remarks: Equatorial thickening (crassitude) and ornament cf mainly verrucae are the features utilized to justify the inclusion of the present specimens within the morphographic circumscription of Synorisporites.

Comparison: The species described above is distinct from all the previously described forms attributed to genus Synorisporites. S. papillensis McGregor (1973, p. 51) stands closest morphologically but differs, however, by possessing dark papillae on the proximal surface. S. downtonensis Richardson & Lister (1969, p. 232) is distinguished by being larger (44-78μm) and possessing convolute and anastomosing muri. S. ? libycus Richardson & Ioannides (1973, p. 278) is merely ornamented with verrucae which "are strictly confined within the equatorial thickening".

Synorisporites variegatus sp. nov.

Plate 10, figs. 1-4

Derivation of name: Latin, variegatus, meaning 'of different sorts', referring to ornament on the distal surface.

1966 'unidentified' McGregor & Owens pl. 28, figs. 17-18, 21-22.

1970 Hymenozonotriletes famenensis Kedo in McGregor pl. 21, figs. 6, 16; pl. 22, fig. 5.

1975 Hymenozonotriletes famenensis Naumova in Higgs pl. 5, fig. 6.

Holotype: US6D 96 120 492.

Type locality: Pope Hollow Section. Along boundary between Carroll and South Vally Townships, Jamestown quadrangle, New York State.

Occurrence: Chadakoin and Cattaraugus Formations, New York State, U.S.A.

Diagnosis: Zonate miospores with more or less distinct equatorial crassitude, distal and equatorial hemispheres sculptured with muri and discrete verrucae; laesurae extending $\frac{3}{4}$ to inner margin of the crassitude, usually terminating in curvaturae perfectae on the equator; rays simple or masked with folds.

Description: Miospores radial trilete; amb roundly triangular with convex sides and rounded apices; margin smooth to lobate. Exine 2-3μm thick distally. Proximal surface laevigate, contact areas well delineated, smooth, bounded by curvaturae perfectae. Distinct to barely distinguishable equatorial crassitude 2-4μm wide. Ornamentation elements consist of irregular muri and discrete to coalescent verrucae, concentrated on the distal surface with frequent encroachment onto the equatorial hemisphere; muri 1-4μm wide, verrucae 1-3μm in diameter. Verrucae sometimes fused into irregular ridges; discrete verrucae dominant to subordinate. Features circular to irregular in plan, rounded to flat topped in profile. Oblique and polar compressions equally frequent. Trilete mark distinct; laesurae straight, simple, usually associated with folds or lips (2 - 5μm) extend, reducing in height, $\frac{3}{4}$ to full spore radius; suturae terminating in curvaturae perfectae which coincide with crassitude through all of their length.

Size range: 49-64μm, mean 55μm (50 specimens measured).

Remarks and Comparison: The species is well ornamented with muri and subordinate verrucae together with equatorial crassitude. It is therefore better accommodated by Synorisporites. S. richardsonii sp. nov. somewhat resembles S. variegatus sp. nov. from which it can be distinguished as it possesses distal ornament of verrucae and coni. Crassitude in S. verrucatus Richardson & Lister 1969 is smooth proximally and distally and the miospores are considerably smaller (16-33μm).

Infraturma ZONATI Potonié & Kremp 1954

Genus SAMARISPORITES Richardson 1965

Type Species: S. orcadensis (Richardson) Richardson 1965

Diagnosis: See Richardson 1965, p. 581.

Remarks: In making Samarisporites a junior synonym, McGregor (1973, p. 58) remarked that the extent of the cavity and the degree of attachmnet between exine layers are insufficient ciriteria for generic differentiation. According to McGregor the genus therefore comes within the morphographic range of Grandispora. The present author departs from McGregor but concurs with Playford (1976, p. 41) in retaining this taxon as separate from Grandispora. Samarisporites is used here in the sense implied by Richardson (1965); i.e. as zonate miospores having a distal ornament of coni, short spinae and/or verrucae.

Samarisporites inusitatus Allen 1965

Plate 10, fig. 5

1965 Samarisporites inusitatus Allen p. 717, pl. 99, figs. 7-9.

Occurrence: Abundant in the Java and Canadaway Formations; a single specimen was also found in the Chadakoin Formation, New York State U.S.A.

Diagnosis: See Allen 1965, p. 717.

Description: Miospores radial trilete; amb subcircular to roundly triangular. Exine two-layered; intexine 1-2.5μm thick, closely appressed to the exoexine; rarely indistinct, subtriangular usually conformable with the amb. Exoexine laevigate to finely infragranulate apart from ornament which is restricted to the distal surface or which projects from all or part of the equator. Proximal

surface laevigate. Ornament consists of cones, 1-3μm wide, 1-4.5μm high; the cones often support a small apical spine. Cones may be discrete, usually fused, or more frequently associated, forming an imperfect reticulum. On some specimens there is a relatively complete reticulum on the distal side. Equatorial flange with occasional compression folds. Trilete mark distinct; laesurae masked with smooth, elevated folds, 1-2μm wide, 3-5μm high, extending to the equatorial margin.

Size range: Exoexine 55-70μm, mean 62μm; intexine 50-60μm, mean 55μm (35 specimens measured).

Comparison: Samarisporites inusitatus Allen (1965) differs from S. triangulatis Allen 1965 in the nature of amb which is circular to roundly triangular rather than triangular.

Samarisporties orcadensis (Richardson 1960, p. 58, pl. 14, fig. 12, text fig. 8) Richardson (1965) possesses an ornament merely of cones which do not support an apical spine. The size range of the Scottish species is considerably greater (96-153μm).

Samarisporites kedoae (Riegel) comb. nov.

Plate 10, figs. 6-7

Non 1953 Hymenozonotriletes argutus Naumova p. 41, pl. 4, fig. 10; pl. 9, fig. 9.

? 1955 Hymenozonotriletes argutus Naumova, in Kedo pl. 4, fig. 4.

1968 Hymenozonotriletes argutus Naumova, in Lanninger p. 144, pl. 24, fig. 15.

1973 Hymenozonotriletes kedoae Riegel p. 94, pl. 15, figs. 1-3.

1974 Samarisporites sp. cf. Hymenozonotriletes acanthyrugosus Chibricova in Becker et al. p. 25, pl. 18, fig. 8.

Non 1974 Ancryospora kedoae (Riegel) Turnau, p. 152, pl. 9, figs. 1-3, 6,7,

Occurrence: Canadaway and Chadakoin Formations, New York State, U.S.A.

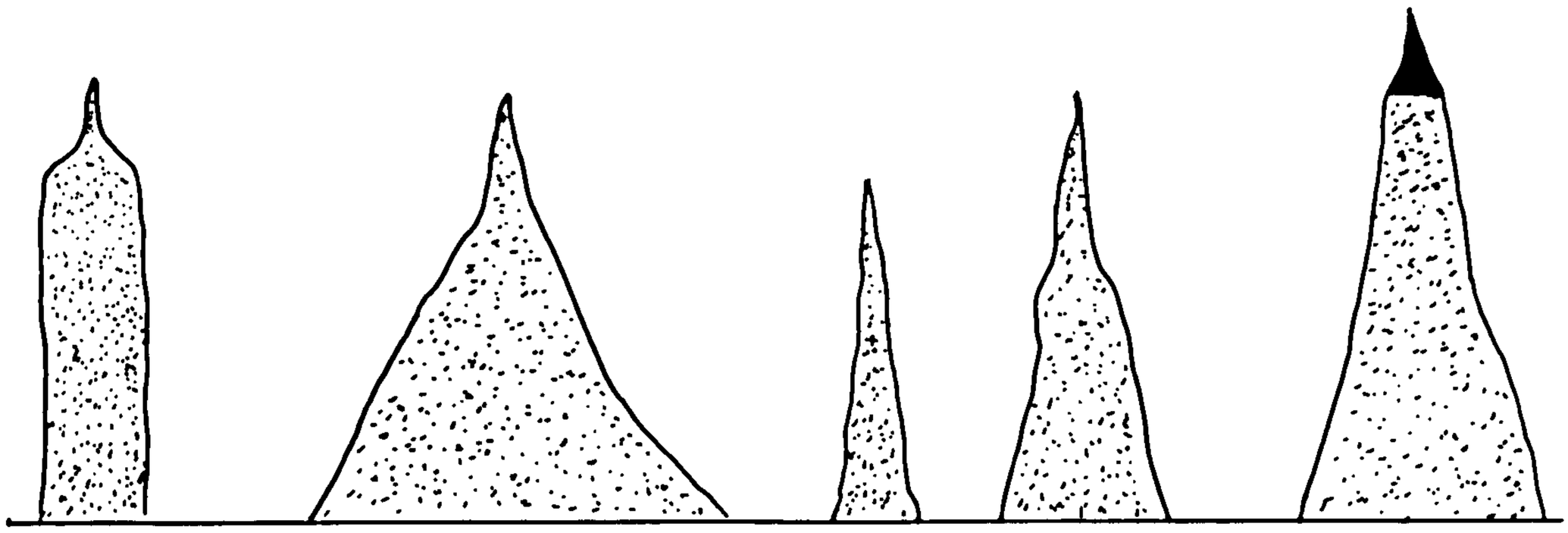
Diagnosis: See Riegel 1973, p. 94.

Description: Miospores radial trilete, zonate, amb subtriangular or oval with convex interradial sides and rounded apices; margin notched and irregular due to the distribution of ornament. Exine two layered, intexine roundly triangular 3-4μm thick (dark) and laevigate; exoexine 1-1.5μm thick, olosely appressed to intexine and extended in the equatorial plane to form a zonate flange. Exoexine laevigate to infrapunctate apart from the ornament which is confined to the distal face and the equatorial hemisphere. Sculptural elements comprise spines and cones of variable shape, height and width (see text fig.6.5). They range 2-8μm in height and up to 5μm in basal width; isolated spines rarely borne, normally connected at their bases. Distance between tips of elements at equator 5-20μm, distance between intexine and equator of exoexine 7-30μm, occasionally more at angles than at interradial region. Trilete mark distinct; laesurae frequently masked with folds, straight or sinuous extending $\frac{3}{4}$ to full intexine radius.

Size range: 67-153μm, mean 110μm, intexine 56-107μm, mean 81μm (40 specimens measured).

Remarks: In its current broadly defined form, the genus Samarisporites Richardson 1965 can reasonably accommodate the species originally described from the Middle Devonian of the Eifel, West Germany.

Comparison: The intexine in S. kedoae is frequently thicker which stains darkly. In the specimens observed the sculptural elements appear to be darker (thicker) near the tip, this feature is evident in the figures illustrated by Riegel (1973), especially in holotype. This effect is also portrayed in Streel's (in Becker et al. 1974, pl. 18, fig. 8) photograph of Samarisporites sp. cf. H. acanthyru-gosus



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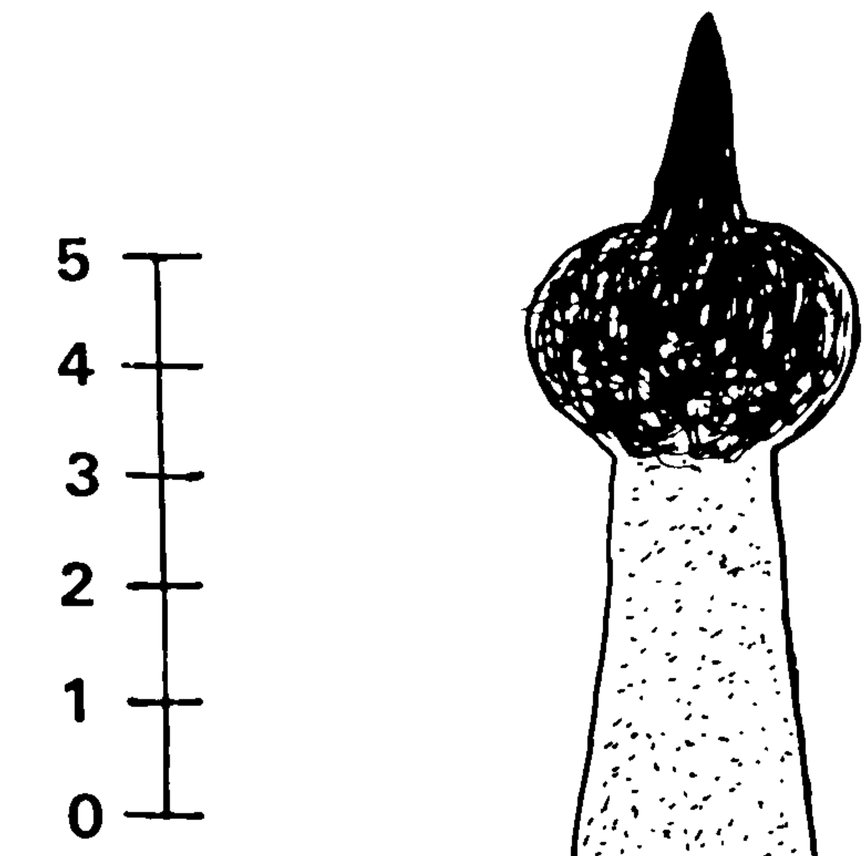


b

Text fig. 6.5. Sculptural elements of (a) Samarisporites kedoae (Riegel) comb. nov.
(b) Samarisporites sp. cf. S. kedoae (Riegel) comb. nov. Lateral views.

Chibricova. Hymenozonotriletes argutus Naumova in Kedo (1955) is placed with question in synonymy with S. kedoae (Riegel) comb. nov. since apparently it seems to lack the characteristic spine structure of the latter; otherwise conspecific with Riegel's species. Another taxon Calyptosporites angulatus Tiwari & Schaarschmidt (1975) would appear to be very close to, if not synonymous with, S. kedcae. The former differs in having bifurcate spines. The thickening near the tip of the element is also evident in Samarisporites sp. cf. S. kedoae. In the latter, however, the thickenings are much more pronounced and it is conceivable that the two forms are end members of a morphological variation.

Samarisporites sp. cf. S. kedoae (Riegel) comb. nov.

Plate 10, figs. 8-9

Occurrence: Rare. Chadakoin Formation, New York State, U.S.A.

Description: Miospores trilete; amb subtriangular to irregular; margin notched. Exine two layered, intexine thick, circular and laevigate; exoexine thin, minutely roughened by fine, dense infrapunctation. The intexine and exoexine are closely appressed and the latter extends in the equatorial plane to form a wide zonate flange. Distal and equatorial hemispheres of exoexine conspicuously sculptured with spinae of distinctive form. Spinae show, overall, a uniform taper from base to sharp point; but approximately two-third to three quarters of the distance from the base of each is a prominent circular swelling up to 4μm wide. Each of these swelling is surmounted by a single spine. Elements are up to 8μm high and 2μm wide at the base (text fig.6.5)Spinae and coni may be interspersed between the

biform elements. Trilete mark distinct; laesurae accompanied by straight or flexuous folds of the exoexine which extend, decreasing in height, $\frac{3}{4}$ to full intexine radius.

Size range: Only one specimen seen measuring 115μm.

Remarks: Sculptural elements appear thicker (darker) towards the top and thinner (lighter) at the base, which may be the result of corrosion pitting.

Genus SPINOZONOTRILETES Hacquebard 1957

Type Species: S. uncatus Hacquebard 1957.

Diagnosis: See Hacquebard 1957, p. 315.

Remarks: The genus is confined to zonate miospores consisting of two wall layers; the intexine and exoexine, which are closely appressed to each other. The exoexine extends equatorially to form a solid flange, ornamented with well-developed spines, otherwise it is laevigate or finely granulose.

Playford (1971, p. 45; 1976, p. 41) and McGregor (1973, p. 58), the latter apparently independently of the former, merged Spinozonotriletes into Grandispora Hoffmeister, Staplin & Malloy; the latter genus as a senior synonym takes priority over the former. In the present work Spinozonotriletes is treated as a genus separate from Grandispora on the basis of exine structure. The latter possesses cavate rather than zonate organisation. (See also remarks under Grandispora).

Spinozonotriletes sp.

Plate 10, fig. 10

Occurrence: Rare. Cattaraugus Formation, New York State, U.S.A.

Description: Miospores radial trilete; amb subtriangular with convex sides and rounded apices. Exine two layered; the inner layer (intexine) thick, distinct, outline conformable with the amb and laevigate; the outer layer (exoexine) also thick and extends at the equator in the form of a thick flange. Exoexine partly folded, infrapunctate to laevigate apart from the ornament which is restricted to the distal and equatorial hemispheres. Ornament consists of relatively long, widely spaced, straight or bent spines which are parallel sided with rounded apices; sometimes the spines taper uniformally from broad bases, they are I4-45 m long and number thirteen to eighteen around the equator. Trilete mark distinct; laesurae accompanied by elevated, sinuous lips, which may simulate exinal folds and almost attain equatorial margin; length of the laesurae equal to the radius of the 'body' of the spore.

Size range: Exoexine 82-I4Iμm, intexine 69-I20μm (7 specimens measured)

Remarks: Owing to its extreme rarity, the form cannot formally be named specifically at this stage. The specimens find suitable inclusion within the genus Spinozonotriletes because of their non-pseudosaccate (zonate) construction.

Comparison: Spinozonotriletes sp. somewhat resembles S. cf. naumovii (Kedo) Richardson, originally recovered by Kedo (I955) from the Givetian of B.S.S.R. and subsequently observed by Richardson (I965, p. 583) and McGregor (I973, p. 6I) from the middle Devonian of Scotland and Canada respectively. The present form differs, however, in having rounded rather than pointed tips to the spines.

Suprasubturma PSEUDOSACCITITRILETES Richardson 1965

Infraturma MONOPSEUDOSACCITI Smith & Butterworth 1967

Genus GRANDISPORA Hoffmeister, Staplin & Malloy emend. Neves & Owens 1966

Type Species: G. spinosa Hoffmeister, Staplin & Malloy 1955

Diagnosis: See Neves & Owens (1966), p. 346.

Remarks and Comparison: Neves & Owens (1966) emended the diagnosis of Grandispora to clarify the nature of attachment of the intexine and exoexine. These are only attached in the region of the trilete mark. The exoexine is sculptured with spinae and/or coni borne on distal and equatorial hemispheres and may encroach slightly onto the proximal surface.

The present author does not concur with Playford (1971, p. 45) and McGregor (1973 p. 58) regarding their broad generic concept of the taxon under consideration. The generic diagnosis formulated by McGregor (loc. cit.) incorporates Spinozonotriletes Hacquebard 1957, Calyptosporites Richardson (1960) 1962 and Samarisporites Richardson 1965 in synonymy with Grandispora. Playford (loc. cit.) failed to observe zonate miospores and regarded Spinozonotriletes as cogeneric with Grandispora. However, contrary to McGregor, Playford did not include Samarisporites within his synonymy listing for Grandispora.

During the present investigation a number of miospores having pseudosaccate structural organization (e.g. Auroraspora, Grandispora and Calyptosporites) on one hand and zonate exine (e.g. Spinozonotriletes and Samarisporites) on the other have been recovered, providing a way to sustain these taxa of different morphological characters as separate from each other.

The diagnosis of Grandispora as restated by Neves & Owens (1966) still remains the basic circumscription of the genus, and is hence followed in this work. The features redefined by these authors are also the principal criteria used to justify the transfer of some of the Russian species to the present genus.

Grandispora corunata Higgs 1975

Plate 11, fig. 1

1975 Grandispora corunata Higgs p. 398, pl. 4, figs. 4-6.

Occurrence: Rare. Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: See Higgs 1975, p. 398.

Size range: Exoexine 51-64 μm, mean 55 μm; intexine 44-52 μm, mode 47 μm (25 specimens measured).

Remarks: The cavate construction of the miospores and their distal and equatorial spinose sculpture support the generic allocation. The specimens recorded during the present investigations are only sparingly represented in the upper part of the sequence; many of them are badly preserved and the inner body is not clearly defined. However, the specimens are comparable in general organization with G. corunata Higgs recorded from the Upper Devonian of Hook Head, County Wexford, Ireland.

Grandispora echinata Hacquebard 1957

Plate 11, figs. 2-3

1957 Grandispora echinata Hacquebard p. 317, pl. 3, fig. 17.

Occurrence: Canadaway, Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: See Hacquebard's description p. 317.

Description: Miospores radial trilete; amb circular, subcircular to more or less triangular. Exine composed of two layers; intexine 1-2μm thick, laevigate, not always clearly defined; exoexine 1-1.5μm thick, usually exhibits an infrastructure of punctations (infrapunctate), ornamented with discrete spines and/or cones. Ornamentation confined to distal surface and project also from all or part of equator; proximal surface laevigate. Spines up to 3μm high and 1μm wide; cones 1-1.5μm high and up to 1μm wide, elements circular in plan, pointed to almost rounded in profile. Sculptural elements variable among specimens but normally uniform on individuals. Trilete mark distinct; laesurae simple, extending to body margin, sometimes masked with elevated, sinuous lips, which may simulate exinal folds and are of variable width (up to 5μm).

Size range: Exoexine 41-69μm, mean 58μm; intexine 35-54μm, mode 45μm (30 specimens measured).

Remarks and Comparison: The specimens of this study are morphologically identical in terms of size, shape and nature of ornament to those recovered by Sullivan 1968 from the Tournaisian of the Cementstone Group in Ayrshire, Scotland. A Russian species recorded from the Tournaisian of Pripyat Depression, Hymenozonotriletes flavus Kedo (1963, pl. 5, fig. 132) bears equivocal, possibly close, relationship with G. echinata.

Grandispora echinula (Naumova) comb. nov.

Plate 11, figs. 4-5

1953 Hymenozonotriletes echinulas Naumova p. 78 (Russian transl.) pl. 17, fig. 22.

Occurrence: Java, Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: See Naumova 1953, p. 78.

Description: Miospores radial trilete; amb subcircular to subtriangular. Exine double layered. Body thin, laevigate surrounded by pseudosaccus and attached to it over proximal surface, outline conformable with amb. Pseudosaccus 1-1.5μm thick, finely infragranulate to laevigate, proximal surface smooth; equatorial and distal hemispheres bear distinctive broad based, discrete spines which taper sharply to almost pointed apices. Spines 6-16 project at the equator, 2.5-7.6μm high, 1-2.5μm wide at their bases. Trilete mark distinct; laesurae straight extending $\frac{1}{2}$ to $\frac{3}{4}$ spore radius, frequently accompanied by sinuous folds up to 7μm high.

Size range: Exoexine 51-70μm, mean 60μm; intexine 42-58μm, mode 50μm (30 specimens measured).

Remarks and Comparison: Assignment to the present genus is endorsed because the pseudosaccate miospores having spinose ornament should eventually be attributed to Grandispora. The most closely comparable category seems to be G. echinata Hacquebard, which can be differentiated by having conate, as well as spinose, ornamentation elements. The Canadian species has a somewhat greater size range (62-93μm). Another taxon illustrated from the Devonian-Carboniferous boundary in the central region of the Russian Platform by Umnova, Hymenozonotriletes facilis Kedo var. decorus Umnova (1971, pl. 3, figs. 53 and 74) seems to be similar in general organization and may be conspecific. However, a detailed comparison is not possible with undescribed Russian specimens. An identical form has also been recorded from the Pripyat Depression by Kedo (1957, pl. 1, fig. 3).

Grandispora macroseta (Kedo) comb. nov.

Plate 11, figs. 7-9

1963 Hymenozonotriletes macrosetus Kedo pl. 6, figs. 149-150.

Occurrence: Chadakoin and Cattaraugus Formations, New York State, U.S.A.

Description: Miospores radial trilete; amb subcircular to sub-triangular. Exine two layered, intexine (body) subcircular, virtually laevigate, covered by pseudosaccus and attached to it over proximal surface. Pseudosaccus infrapunctate. Body usually eccentrically placed, imperceptible to fairly distinct. Distance between body and pseudosaccus subequal. Pseudosaccus ornamented with gently tapering spines, 8-22 μm high, 2.5 μm wide at bases, 1 μm wide at tips. Trilete mark distinct; laesurae straight, extending $\frac{3}{4}$ to full body radius, accompanied by flexuose exoexinal folds which normally extend, decreasing in height to the pseudosaccus margin; ray folds up to 8 μm high.

Size range: Exoexine 71-119 μm, mean 90 μm; intexine 43-77 μm, mode 53 μm (30 specimens measured).

Remarks and Comparison: Pseudosaccate organization and spinose ornament makes inclusion within Grandispora entirely satisfactory.

Although sharing similar sculptural and structural attributes, Grandispora macroseta (Kedo) comb. nov. and G. echinula can be differentiated from each other as the latter incorporates smaller miospores (51-70 μm) and sculptural elements (2.5-7.6 μm). Comparison can also be drawn between G. microseta (Kedo) Streel in Becker et al. and G. macroseta (Kedo) comb. nov; the former is distinct in having a smaller size range (53 and 54 μm see Streel in Becker et al. 1974, p. 26) and possessing more or less parallel sided spines with non-pointed apices.

Grandispora sp. cf. G. spinosa Hoffmeister,
Staplin & Malloy in Massa & Moreau-Benoit 1976

Plate 11, figs. 10-11

cf 1976 Grandispora spinosa Hoffmeister, Staplin & Malloy;
Massa & Moreau-Benoit pl. 5, fig. 5.

Occurrence: Cattaraugus Formation, New York State, U.S.A.

Size range: Two specimens seen measuring 70 and 73 µm respectively.

Remarks: Two specimens have been encountered during the present investigation which are comparable with those illustrated by Massa & Moreau-Benoit of western Libya from the Upper Givetian to Upper Famennian. Firm attribution to the American species is hindered by the rudimentary nature of the ornament and the extreme rarity of the examples observed in the present material.

Genus CALYPTOSPORITES (Richardson) Richardson 1962

Type Species: C. velatus (Eisenach) Richardson 1960.

Diagnosis: See Richardson 1960, p. 52.

Remarks: Playford (1971, p. 45) and McGregor (1973, p. 58) interpret Calyptosporites as being synonymous with Grandispora. The present writer rejects this suggestion and uses the genus in the sense diagnosed by Richardson (1960, 1962) i.e. for pseudosaccate species ornamented with cones and spines, having subtriangular outlines to both the intexine and exoexine with prominent ray folds.

Calyptosporites perclarus sp. nov.

Plate 12, figs. 1-7

Derivation of name: Latin, perclarus, meaning very beautiful, referring to beautiful nature of varied ornamentation elements.

Holotype: Plate 12, figs. 1-2. US6E 299 125339.

Type Locality: Pope Hollow Section, along boundary between Carroll and South Vally Townships, Jamestown quadrangle, New York State.

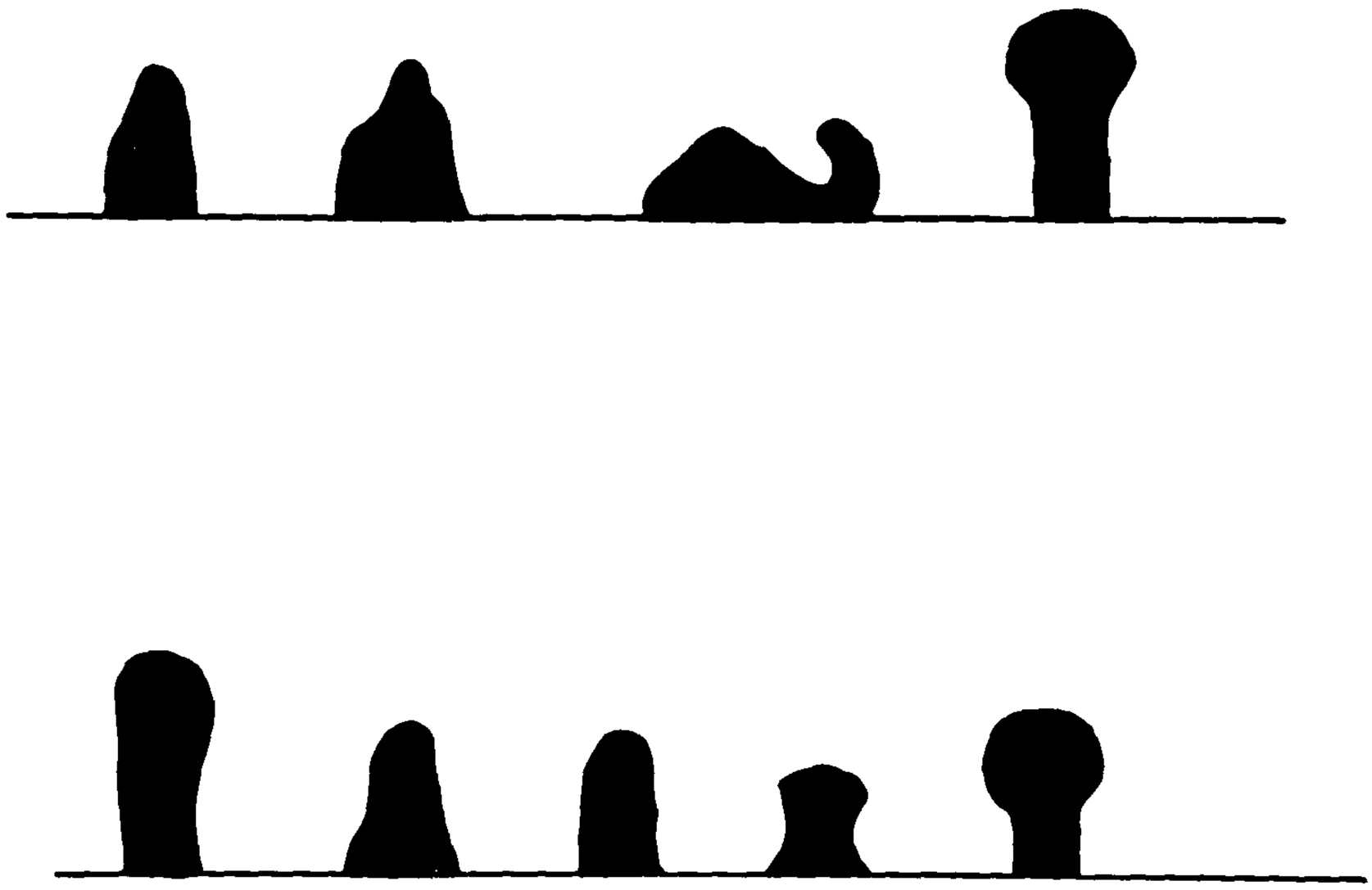
Occurrence: Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: Pseudosaccate miospores, ornamented with varied elements including pila, bacula, cones 1-4μm high, reduced or absent on proximal hemisphere; laesurae distinct to perceptible, frequently associated with lips which simulate exinal folds.

Description: Miospores radial trilete; amb subtriangular with convex sides and rounded apices. Exine double layered; intexine (body) laevigate up to 3μm thick, subcircular to subtriangular usually conformable with amb, covered with pseudosaccus (exoexine) and attached to it over proximal surface, most probably in the region of laesurae. Pseudosaccus 1-2μm thick, infrapunctate to infragranulate; independent sets of concentric and arcuate compression folds commonly developed on the distal side of the pseudosaccus; distal and equatorial hemispheres bear a closely set ornament of varied elements including pila, bacula and cones. Height of elements 1-4μm, basal width 1-2μm, stalk 1μm thick, up to 3μm high and spherical head (on stalk) 1.5μm in diameter. Discrete and coalesced ornament equally developed. Representatives usually preserved in polar compressions. Trilete mark distinct; laesurae straight extending full body radius, rarely proceed further, frequently associated with lips which simulate exinal folds, 2-3μm wide, up to 5μm high.

Size range: Exoexine 48-65μm, mean 56μm, intexine 34-45μm, mean 39μm (50 specimens measured).

Remarks and Comparison: Subtriangular amb together with ray folds are regarded as sufficient criteria to warrant their inclusion within the genus Calyptosporites.



0 1 2 3

Scale in microns

Text fig. 6.6. Sculptural elements of Calyptosporites perclarus sp. nov. Lateral views.

This species shows certain similarities to some previously described forms, but in no instance could identity with them be established confidently. G. inculta Allen (1965) is ornamented with cones only which are 1-2μ m in height and width and possesses longer laesurae; moreover, it has a greater size range 51-86μm. G. setosa Clayton & Graham (1974, p. 578) is somewhat comparable with C. perclarus sp. nov. from which it can be differentiated by having smaller ornament (up to 2μm high). Should the Irish species prove to have larger ornament then it would be conspecific. A miospore form Endoculeospora gardzinskii Turnau (1975, p. 518, pl. 7, figs. 1-3), described from Lower Carboniferous deposits of northern Poland, appears to be closely akin to the species under consideration. The Polish species differs, however, in having weakly developed lips, as is suggested by the photographs (measurement not given), smaller ornamentation elements (up to 1μ m long) and a circular to subcircular amb. Hymenozonotrilete acanthyrugosus Chibrikova (1959, pl. 11, fig. 1) appears to be similar. The Russian description is insufficiently explicit (e.g. about sculptural detail) for a close comparison to be made, but it is much larger (90-110μ m) than C. perclarus and its sculptural elements probably comprise spines and cones.

Genus RHABDOSPORITES Richardson 1960

Type Species: R. langi (Eisenach) Richardson.

Diagnosis: See Richardson 1960, p. 53.

Remarks: Rhabdosporites is instituted to accommodate trilete pseudosaccate miospores. Pseudosaccus (exoexine) sculptured with closely spaced minute rods, that are parallel sided elements

with almost truncated tips. Intexine (body) laevigate, pseudosaccus is frequently collapsed into folds, perhaps acquired during preservation.

Comparison: Remysporites Butterworth and Williams 1958 differs in having laevigate to microreticulate pseudosaccus. Calyptosporites Richardson 1962 is also sculptured but the latter has an ornament of cones and spines. Auroraspora Hoffmeister Staplin and Malloy, Richardson (1960) is a laevigate pseudosaccate taxon.

Rhabdosporites langi (Eisenach) Richardson 1960

Plate 12, figs. 11-12

1925 Type B Lang p. 256, fl. 1, figs. 3-6.

1944 Triletes langi Eisenach p. 112, pl. 2, fig. 4.

Occurrence: Rare. Chadakoin Formation, New York State, U.S.A.

Diagnosis: See Richardson 1960, p. 54.

Description: Miospores radial trilete, amb subcircular to irregular due to folds. Exine two layered, intexine up to 4μm thick (as measured along outline) subcircular, junction between pseudosaccus and body distinct, body normally eccentrically placed. Pseudosaccus comparatively thinner (up to 2μm), frequently folded, folds irregular; ornamented with densely spaced rods over proximal, distal and equatorial sides, rods often with truncated tips. Ornament features 0.2 to less than 1μm high. Trilete mark distinct; laesurae ½ to almost spore radius, pseudosaccus normally folded above the rays.

Size range: Exoexine 150-170μm, mean 160μm; intexine 102-114μm, mean 108μm (7 specimens measured).

Remarks and Comparison: The population measured from the Dexterville Member of the Chadakoin Formation comprised only 7 specimens which conform with those described by Richardson (1960) from the Lower Givetian, Middle Old Red Sandstone, Cromarty, Scotland differing only in the nature of body which appears to be thicker in the studied material. Hymenozonotriletes platyrugosus Naumova 1953, pl. 8, fig. 10 differs in possessing larger body, simple and longer laesurae.

Rhabdosporites parvulus Richardson 1965

Plate 12, figs. 8-10

1965 Rhabdosporites parvulus Richardson p. 588, pl. 93, figs. 5-7.

Occurrence: Rare, in the Chadakoin, abundant in the Cattaraugus Formation, New York State and Pennsylvania, U.S.A.

Diagnosis: See Richardson 1965, p. 588.

Size range: Exoexine 62-80μm, mean 70μm; intexine 42-60μm, mean 52μm (30 specimens measured).

Remarks: The examples recovered during the present investigation resemble those described from the Orcadian Basin, Scotland by Richardson (1965). This species has sporadically been encountered in the Chadakoin and Cattaraugus Formations.

Genus RETISPORA Staplin 1960

Type Species: R. florida Staplin 1960.

Diagnosis: See Staplin 1960, p. 32.

Remarks: The genus Retispora embraces two layered miospores consisting of an intexine and an exoexine. The latter is strongly reticulate on the distal surface.

Retispora lepidophyta (Kedo) Playford 1976

Plate 13, figs. 1-3

1957b Hymenozonotrilete lepidophytus Kedo p. 34 (English transl.), pl. 2, figs. 19-21.

1962 Leiozonotriletes naumovae Balme & Hassell p. 18, pl. 4, figs. 10-12.

1962 Endosporites lacunosus Winslow p. 44, pl. 16, figs. 1-5.

1964 Leiozonotriletes sp. Wray pl. 1, fig. 25.

1967 Hymenozonotriletes lepidophytus Kedo in Ownes & Streel p. 144, pl. 1, figs. A-G.

1971 Hymenozonotriletes lepidophytus Kedo in Kedo & Goloubtsov p. 26, pl. 1 , figs. 1-16.

1974 Spelaeotriletes lepidophytus (Kedo) Streel in Becker et al. p. 26, pl. 20, figs. 2-4.

1976 Retispora lepidophyta (Kedo) Playford p. 45, pl. 10, figs. 1-15.

Occurrence: Cattaraugus and upper part of the Chadakoin Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: See Playford's (1976) description, p. 45.

Description: Miospores radial trilete; amb subtriangular with convex sides and rounded apices, ranging from subtriangular to subcircular, periphery smooth to slightly undulate. Exine composed of two layers; intexine 1-2μm thick probably laevigate, more or less conformable with amb and attached to exoexine over proximal surface; distance from body to equatorial margin 18-35.7μm which is equal to subequal. Exoexine 1.5-2.5μm thick occasionally slightly thicker at the equatorial margin, finely structured (punctate to infragranulate); distally ornamented with circular, polygonal to irregular lacunae, 5μm in maximum diameter, bounded by muri 2-4μm wide. Small verrucae and cones 1μm or less in basal diameter and almost 2μm high frequently observed on the muri. Independent sets of compression folds commonly developed on the exoexine; muri some-

Measurements in descending order.

Sample no.	Formation	Size range in microns.	No. of specimens measured.
NY95C	Cattaraugus	63	1
US6G	Cattaraugus	132.6	1
US6E	Cattaraugus	114	1
US6C	Cattaraugus	-	1 (Fragmentary)
US6A	Cattaraugus	81 and 137	2
US5	Chadakoin	60	1
NY96H	Chadakoin	50	1
NY96G	Chadakoin	102 and 158	2
NY96E	Chadakoin	94.3	1
NY96E	Chadakoin	-	1 (Fragmentary)
NY96E	Chadakoin	140	1
NY96C	Chadakoin	102 - 114.7	3
NY96C	Chadakoin	79 - 84	4
NY96B	Chadakoin	130	2 (1 Fragmentary)

Table 6.1. showing the size range and stratigraphical distribution of R. lepidophyta (Kedo) Playford and R. lepidophyta var. granda (Kedo) comb. nov. in the samples investigated.

times discontinuous on distal exoexine. Trilete mark distinct to inconspicuous; laesurae frequently associated with lips or folds, extending to the spore radius or nearly so, where weak curvaturae are occasionally perceptible.

Size range: Exoexine 50-II4.7μm, mean 70μm; intexine 30-60μm, mean 45μm (I5 specimens measured).

Remarks: The species has been described under various disguises by many palynologists. Because of its inordinately wide geographical distribution and restricted vertical range, R. lepidophyta is regarded as a key biostratigraphic index for the uppermost Devonian (latest Famennian, Fa2d, to Strunian, TnIa, and lower TnIb, interval). The remarkable geographical extent of the taxon has been summarized by many workers. Owens & Streel (I967) and Richardson (I969) outlined the previous record of the species from different parts of the world. Streel (I974, fig. I) plotted the geographic spread of R. lepidophyta on Smith, Briden & Drewry's (I973, text fig. II, map 6) continental assembly for the Lower Carboniferous. Recently Playford (I976, p. 46) amply documented work already published on the species under consideration.

The representatives of R. lepidophyta that have been recorded during the present study from samples NY96B to US95 (from base of the Ellicott Member of Chadakoin Formation to top of the Cattaraugus Formation) are a few in number. In a total of eleven productive samples only 22 specimens of R. lepidophyta including var. granda have been observed. Some of the specimens are fragmentary and poor in preservation, so it was not therefore, possible to make a biometric study of the successive populations. Further, it will be evident from Table 6.I that Streel's biometric zones are not applicable to the present material. The specimens having different size ranges are equally distributed in the sequences investigated. Nevertheless, some measurements have been taken and these are presented in Table 6.I.

Retispora lepidophyta var. granda
(Kedo) comb. nov.

Plate 13, figs. 5-6

1971 Hymenozonotriletes lepidophytus Kedo var. grandis Kedo in Kedo & Goloubtsov pl. 2, fig. 4.

Occurrence:

Size range: Exoexine 130-158 μm; intexine 80-100 μm (5 specimens measured).

Remarks: R. lepidophyta var. grandia is comparable in morphological characters with R. lepidophyta. The former diverges slightly in having a greater size range. Lacunae are 3-10 μm in maximum diameter and muri vary in size from 3-6 μm. Trilete mark is distinct and laesurae are found associated with folds which are straight or slightly sinuous and invaginated at the radial positions.

Genus SPELAEOTRILETES Neves & Owens 1966

Type Species: S. triangulatus Neves & Owens 1966.

Diagnosis: See Neves & Owens 1966, p. 342.

Remarks: Spelaeotriletes Neves & Owens was found to incorporate cavate trilete miospores consisting of two layers; the intexine and exoexine are in contact only in the region of the laesurae. Exoexine is sculptured with a variety of elements, including coni, grana, and verrucae which are confined to distal and equatorial quarters especially in the radial positions about the proximal surface. Contact areas and inner body laevigate.

Spalaeotriletes densatus sp. nov.

Plate 13, figs. 7-9

Derivation of name: Latin, densus, meaning close, referring to high density of sculptural elements.

Holotype: Plate 13, fig. 8, US6D 296 117718.

Type locality: Pope Hollow Section, along boundary between Carroll and South Vally Townships, Jamestown quadrangle, New York State.

Occurrence: Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: Pseudosaccate miospores ornamented on distal and equatorial hemispheres with grana and coni up to 1μm high and wide; intexine laevigate; laesurae simple or accompanied by folds, extending $\frac{3}{4}$ to full spore radius; ray extremities joined with curvaturae imperfectae.

Description: Miospores radial trilete; amb subcircular to sub-triangular with convex sides and rounded apices; margin smooth to finely granulate. Exine two layered; intexine laevigate, up to 1μm thick, normally eccentrically placed, distance between body and pseudosaccus equal to subequal, junction distinct. Exoexine 1.5-2.5μm thick, bearing closely set ornament of minute grana and/or coni which do not exceed 1μm in height and diameter, confined to distal and equatorial regions of the proximal hemispheres, contact areas laevigate. Ornamentation elements discrete, rounded to pointed in profile, circular to irregular in plan. Trilete mark distinct; laesurae straight, occasionally slightly sinuous, simple or accompanied by lips or folds up to 2μm raised and wide; laesurae extending $\frac{3}{4}$ to full spore radius, joined with curvaturae imperfectae at their extremeties.

Size range: Exoexine 38-51μm, mean 44μm; intexine 23-41μm, mean 32μm (40 specimens measured).

Comparison: The most closely comparable category described to date seems to be Spelaeotriletes crustatus Higgs (1975 p. 399, pl. 6, figs. 4-6). There is a morphological overlap between the Irish species described from Upper Devonian and Lower Carboniferous deposits of Hook Head and S. densatus sp.nov. but Higgs' species is distinct in having a greater size range (55-110μm, mode 70μm), prominent ray folds (up to 7μm high) and longer sculptural elements (up to 2μm). Moreover, apical papillae are also discernible in some of the specimens described from Ireland. S. resolutus Higgs (1975 p. 400, pl. 6, figs. 7-9) displays conate, baculate and pilate sculptural features.

Spelaeotriletes microverrucosus (Kaiser) comb. nov.

Plate 13, figs. 10-11

1970 Hymenozonotriletes microverrucosus Kaiser p. 110, pl. 23, fig. 11.

Occurrence: Rare. Chadakoin Formation, New York State, U.S.A.

Diagnosis: See Kaiser 1970, p. 110.

Description: Miospores radial trilete; amb subcircular. Exine two layered. Intexine 2μm thick (dark) laevigate, outline slightly more circular than the amb, eccentrically placed. Exoexine thin, infrapunctate with compression folds, attached to intexine only over proximal surface; bears an ornament of low, discrete verrucae, 1.5μm high, up to 2μm wide. Trilete mark distinct; laesurae hardly discernible, straight, with low folds 2μm high. Length of rays full spore radius and terminating in curvaturae which are poorly developed and may be defined as a change in exine thickness, coincident with the equator.

Size range: Exoexine 60μm, intexine 42μm (only one specimen measured).

Remarks: The species is here transferred to the genus Spelaeotriletes Neves & Owens (1966) because of being pseudosaccate which is sculptured with discrete verrucae. The population recorded by Kaiser (1970) comprise 7 specimens which are slightly smaller (40-50μm) than the only representative observed during the present investigation.

Comparison: The species most closely comparable to Spelaeotriletes microverrucosus (Kaiser) comb. nov. appears to be Hymenozonotriletes krestovnikovii Naumova (1953, pl. 9, fig. 7) which occurs in the Upper Devonian of the Russian Platform. The latter is distinct, however, in possessing seemingly coarser sculpture whose height seems to be greater than the basal diameter. There are no traces of curvaturae at the ray extremities.

Another closely comparable, if not identical, form has also been illustrated by McGregor (1970 pl. 22, fig. 15) from the Sunbury Formation (? Upper Famennian) Canada.

Genus AURORASPORA Hoffmeister, Staplin & Malloy emend. Richardson 1960

Type Species: A. solisorta Hoffmeister, Staplin & Malloy 1955.

Diagnosis: See Richardson (1960), p. 49.

Remarks & Comparison: Richardson (1960) proposed the emended diagnosis of the genus Auroraspora to illustrate the absence of a limbus in the pseudosaccus of the latter. The limbus is regarded as a characteristic of the taxon Endosporites.

The genus Auroraspora is characterized by incorporating pseudosaccate (cavate) forms which have laevigate wall layers; the intexine (an inner body) and an exoexine (pseudosaccus). Some of the species described below bear a superficial resemblance to those of the genus Rugosposa Neves & Owens (1966, p. 350). However, the

present forms are accommodated within the taxon Auroraspora because they possess no microverrucose ornament. This ornament is a significant feature of the genus Rugospora (see Neves & Owens, p.350).

The author's decision to attribute some of the present forms to the Russian species is supported by Kedo (Pers. Comm. 1976).

Representatives have been observed, occurring profusely at certain horizons, throughout the sequence studied. A wide variation in morphographic features occurs, including large and/or very minute comprehensive folds covering the pseudosaccus. The generic entity, however, remains the same as that restated by Richardson (1960) because the patterns of conspicuous folding are not regarded as additional sculptural features worthy of generic status.

The distinctive appearance of certain species contributes to their usefulness as markers. The incoming and maximum frequency of these taxa are used for a reliable zonation. In this study the first occurrence of certain forms is used to define the base of the HL assemblage zone.

Auroraspora callosa (Kedo) comb. nov.

Plate 14, figs. 1-3

1974 Hymenozonotriletes callosus Kedo, p. 39, pl. 10, figs. 8-9.

Occurrence: Chadakoin Formation, Dexterville and Ellicott members; New York State and Pennsylvania, U.S.A.

Diagnosis: See Kedo 1974, p. 39.

Description: Miospores radial trilete; amb circular to subcircular; periphery smooth. Exine two layered; intexine up to 1.5μm thick, subcircular to subtriangular, laevigate, and attached to the exoexine (pseudosaccus) over the proximal surface only, most

probably in the region of the laesurae; independent sets of concentric and arcuate compression folds usually developed along outer margin of the intexine. Exoexine thin, finely infrapunctate, rarely folded, sometimes appearing shagrinate, which may be the result of corrosion pitting. Trilete mark distinct to obscured; laesurae simple, straight, extending full body radius.

Size Range: Exoexine 58.6 - 73.9μm, mean 65μm; intexine 33 - 42μm, mean 36μm (30 specimens measured).

Remarks and Comparison: Specimens described above comply with the description given by Kedo (1974) but diverge slightly in the length of laesurae which extend beyond the body radius in the specimens from the U.S.S.R. Another of Kedo's species, Hymenozonotriletes explicatus Kedo (1974, p. 38, pl. 10, figs. 4-7), probably a species of the genus Auroraspora, appears to be similar but differs on the seemingly slight ground that it possesses small folds at the end of each ray.

Auroraspora commutata (Naumova) Dolby M.S. 1970

Plate 14, figs. 4-5,7

1953 Hymenozonotriletes commutatus Naumova p. 77, p. 17, figs. 12-13; pl. 18, fig. 28.

1970 Auroraspora commutata (Naumova) Dolby M.S. p. 89, pl. 9, figs. 12-13.

Occurrence: Chadakoin Formation, New York State and Pennsylvania, U.S.A.

Diagnosis: See Naumova (1953), p. 77.

Description: Miospores radial trilete; amb circular to subcircular, periphery smooth to wavy. Exine two layered; intexine distinct, subcircular, virtually laevigate, and 1.5-3μm in thickness; intexine attached to exoexine over proximal surface only. Exoexine up to 1.5μm thick with rough appearance, laevigate or infrapunctate. Exoexine often with relatively large scale radial folds, sometimes

extending from the sutural termini to the equator. Trilete mark distinct to indiscernible due to thick nature of body; laesurae, where visible, straight, bordered by lips, 2.5-4μ m wide; suturae extending $\frac{3}{4}$ to full body radius.

Size Range: Exoexine 51 - 70μ m, mean 61μ m; intexine 36 - 45.9μ m, mean 40μ m; ratio of body to pseudosaccus 53-67% (30 specimens measured).

Comparison: A closely comparable form appears to be A. solisorta Hoffmeister, Staplin & Malloy recorded from the Mississippian of Kentucky, U.S.A. However, A. solisorta differs in having extremely thin exoexine which is usually finely folded, while in A. commutata the exoexine is radially folded giving a corrugated appearance.

Auroraspora commutata var. major (Kedo) comb. nov.

Plate 14, fig. 6

1957 Hymenozonotriletes commutatus Naumova var. major Kedo p. 31, pl. 2, fig. 11.

Occurrence: Cattaraugus Formation; New York State, U.S.A.

Size Range: Exoexine 86μ m; intexine 50μ m (one specimen measured).

Remarks: The specimen is identical morphologically to A. commutata but differs by being larger in size. A. commutata var. major has a restricted vertical range when compared with its parent species.

Auroraspora micromanifesta (Hacquebard) Richardson 1960

Plate 14, figs. 8-9

1956 Hymenozonotrilete aff. variabilis Naumova in Ishchenko p. 62, pl. 11, figs. 129-130.

1957 Endosporites micromanifestus Hacquebard p. 37, pl. 3, fig. 16.

1971 Discernisporites micromanifestus (Hacquebard) Sabry & Neves pl. 3, fig. 11.

Occurrence: Rare, Chadakoin (Dexterville Member) and Cattaraugus Formations New York State, U.S.A.

Description: Miospore radial trilete; amb convexly triangular with rounded apices; periphery smooth. Exine two layered; intexine distinct, subcircular, laevigate, outline more or less conformable with amb. Exoexine 1-2μm thick, smooth or finely infrapunctate, rarely folded. Trilete mark distinct; laesurae straight, accompanied by lips or folds up to 3μm wide; suturae extending almost to the equator.

Size Range: Exoexine 70 and 100μm; intexine 50 and 80μm (Two specimens measured).

Remarks and Comparison: The species described above is extremely rare in the areas investigated. A. micromanifesta has widely been reported under various disguises (see synonymy list) from Devonian and Carboniferous (Namurian) sediments. Hymenozonotriletes granulatus (Naumova) Jush. (in Kedo 1963, pl. 5, figs. 125-127) from the Tournaisian of Pripyat Depression (U.S.S.R.) and Bertelsen's (1972, pl. 22, fig. 6) spore labelled Discernisporites cf. micromanifestus are probably examples of the species.

Auroraspora multirugata (Kedo) comb. nov.

Plate 14, fig. 10

1974 Hymenozonotriletes multirugatus Kedo p. 37, pl. 10, figs. 1-3.

Occurrence: Cattaraugus Formation, New York State, U.S.A.

Diagnosis: See Kedo 1974, p. 37.

Description: Miospores radial trilete; amb circular to sub-circular; periphery wavy. Exine two layered; intexine distinct, laevigate, circular and 1.5-2.5μm in thickness; intexine attached to exoexine over proximal surface only. Exoexine up to 2μm thick, laevigate to infrapunctate, with numerous fine, randomly dispersed,

sinuous wrinkles. Trilete mark distinct; laesurae straight, simple, extending $\frac{3}{4}$ to full body radius.

Size range: Exoexine 61.2-87μm, mean 74μm; intexine 51-71μm, mean 62μm (25 specimens measured).

Remarks: In the original description, Kedo (1974, p. 37), indicated that spores sometimes exhibit a single large fold. The present author, unfortunately, could not detect even a single specimen showing this feature.

Auroraspora pallida (Naumova) comb. nov.

Plate 14, figs. 11-12

1953 Hymenozonotriletes pallidus Naumova p. 78, pl. 17, figs. 18-19

Occurrence: Canadaway, Chadakoin and Cattaraugus Formations; New York State and Pennsylvania, U.S.A.

Diagnosis: See Naumova 1953, p. 78.

Description: Miospores radial trilete; amb convexly triangular, periphery undulant. Exine two layered; intexine distinct, conformable in outline with amb, virtually laevigate and 1.5μm in thickness; intexine attached to exoexine over proximal surface only, comprising approximately $\frac{3}{4}$ of overall diameter. Exoexine 1μm thick, laevigate to scabrate. Trilete mark distinct; laesurae straight, simple or accompanied by folds or lips, 1-2.5μm in overall breadth; suturae extending $\frac{3}{4}$ to full body radius.

Size range: Exoexine 29-43.3μm, mean 37μm; intexine 25-33μm, mean 30μm (40 specimens measured).

Remarks: The specimens identical to Naumova's species have been observed widely during the present investigation.

Auroraspora papillara (Kedo) comb. nov.

Plate 14, figs. 1-3

1974 Hymenozonotriletes papillaris Kedo p. 33, pl. 8, fig. 8.

Occurrence: Rare, Chadakoin Formation (Ellicott Member.)
Pennsylvania, U.S.A.

Diagnosis: Miospores radial trilete; amb subcircular to oval, periphery indented. Exine two layered; intexine thick, virtually laevigate; independent sets of arcuate compression folds usually developed on the intexine. Outer enveloping layer (exoexine) thin laevigate or infrapunctate, with numerous fine, closely set, sinuous wrinkles and folds. Trilete mark distinct; laesurae straight, simple or accompanied by folds; suturae extending spore body radius.

Size range: Exoexine 70-90μm, mean 80μm; intexine 50-70μm, mean 60μm (30 specimens measured).

Remarks: In A. papillara (Kedo) comb. nov., originally described by Kedo from Famennian deposits of the Turovskii Depression Bielorussia S.S.R., small irregular patterns of folding are developed which extend to the periphery giving a characteristically indented outline and no room for development of radial folding.

Auroraspora cf. papillara (Kedo) comb. nov.

Plate 15, figs. 1-2

cf. 1974 Hymenozonotriletes papillaris Kedo, p. 33, pl. 8, fig. 8.

Occurrence: Rare. Chadakoin Formation (Ellicott Member)
Pennsylvania, U.S.A.

Description: Miospores radial trilete; amb subcircular to oval, periphery smooth to lobate. Exine two layered, intexine 1.5-2μm thick, subcircular, outline conformable with amb, smooth, covered by exoexine (pseudosaccus) and attached to it over proximal surface,

most probably in the region of laesurae. Exoexine up to 1.5μ m thick, laevigate, infrapunctate and densely wrinkled. Trilete mark distinct; laesurae straight, rarely sinuous, simple or accompanied by exoexinal folds; suturae extending spore body radius.

Size range: Exoexine 64-85μ m, mean 74μ m; intexine 42-66μ m, mean 54μ m (25 specimens measured).

Remarks and Comparison: The spores are obviously very close to those described by Kedo (1974) as Auroraspora (al. Hymenozonotrilete) papillara (Kedo) comb. nov. Assignment to the latter category could not, however, be made with absolute conviction, because the pseudosaccus in the present form is densely wrinkled into fine folds.

Auroraspora poljessica (Kedo) Streel (in Becker et al 1974).

Plate 15, figs. 3-5

1957 Hymenozonotriletes poljessicus Kedo p. 36, pl. 3, figs. 5-7.

1974 Auroraspora poljessica (Kedo) Streel in Becker et al. p. 26, pl. 20, figs. 8-14.

Occurrence: Chadakoin and Cattaraugus Formations; New York State and Pennsylvania, U.S.A.

Diagnosis: See Kedo 1957, p. 36.

Description: Miospores radial trilete; amb subcircular to oval; periphery smooth to slightly wavy. Exine two layered; intexine distinct, apparently laevigate, always heavily folded and attached to the exoexine in the region of the laesurae. Exoexine thin, finely infrapunctate, with wrinkled surface. Numerous fine wrinkles give a rough appearance to the spore. Trilete mark distinct, sometimes obscured by the folding; laesurae straight, simple, extending ¾ to full body radius.

Size range: Exoexine 66-79μ m, mean 72μ m; intexine 45-61μ m, mean 51μ m (30 specimens measured).

Remarks and Comparison: Some of the specimens illustrated by Streel (in Becker et al. 1974) may not be true representatives of the species because they exhibit (especially as on pl. 20, figs. 9 and 12) some sculptural elements (as suggested by the photographs) i.e. baculae and coni. The presence of the latter elements is a feature against the generic character of the genus Auroraspora. The writer's opinion to accommodate the present form within the morphographic circumscription of A. poljessica is upheld by Kedo (Pers. Comm., 1976). Higgs' (1975, pl. 5, fig. 10) spore labelled Hymenozonotriletes solisortus is probably a bona fide example of the present species.

Auroraspora prostata sp. nov.

Plate 15, figs. 6-10

Derivation of name: Latin, prostatus, meaning projecting, referring to the patterns of folding on the pseudosaccus.

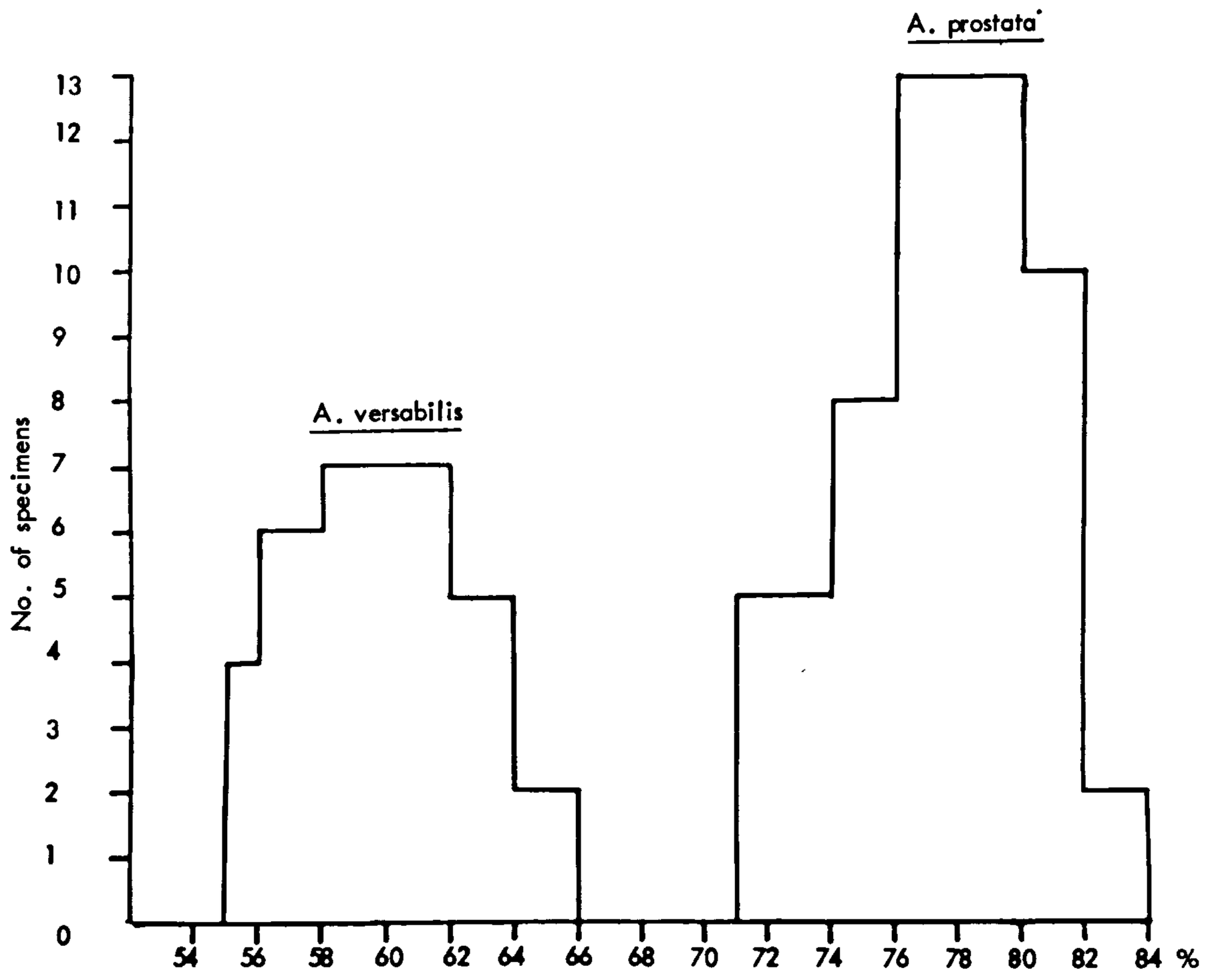
Holotype: Plate 15, fig. 6. NY96C 56 1203553.

Type locality: East of Smethport, road cut on route 6, Chadakoin Formation, Pennsylvania, U.S.A.

Occurrence: Chadakoin Formation (Ellicott Member) Pennsylvania, U.S.A.

Diagnosis: Amb subcircular to oval, more or less conformable with inner body. Exoexine thin, often wrinkled into sinuous folds which project at the amb. Trilete mark distinct to indistinct; laesurae simple or associated with folds.

Description: Miospores radial trilete; amb convexly triangular oval to subcircular, periphery undulating. Exine two layered; intexine distinct, outline more or less conformable with amb, laevigate and up to 2μm thick; intexine attached to exoexine over proximal surface. Concentric compression folds occasionally developed



Text fig. 6.7. A histogram showing the percentage ratio of spore body radius to pseudosaccus radius in the two species of the genus Auroraspora.

on the distal surface of the intexine. Exoexine laevigate to finely infrapunctate and wrinkled. Wrinkles short, curved, arranged more or less radially and project at the amb. Trilete mark distinct sometimes obscured by the folding; laesurae simple or accompanied by folds up to 2μm wide, suturae extending $\frac{3}{4}$ to full body radius.

Size range: Exoexine 63.7-89μm, mean 74μm; intexine 53.5-63.7μm; ratio of body to pseudosaccus 71-80% (36 specimens measured).

Remarks and Comparison: The species described above is distinct from previously described species of the genus Auroraspora by its characteristic patterns of folding which give a corrugated shape to the spore. Folds are wider at the polar region, but are pointed and narrower towards equator. Length and width of folds could not be measured as these are sinuous and overlapped. Kedo (1976 Pers. Comm.) remarked that there is no record of such a specimen in the literature.

Some of the specimens of A. prostata may be mistaken for A. versabilis (Kedo) Turnau. Total diameter as well as body diameter overlap between A. versabilis and A. prostata. However, the ratio of body to total diameter is a useful parameter for distinguishing species, which is claculated and plotted on text fig. 6.7. The figure shows that Kedo's species is distinct from the one described here.

Auroraspora prostata sp. nov. var. elongata var. nov.

Plate 15, figs. 11-12

Derivation of name: Latin, elongatus, meaning prolonged, referring to nature of folds on exoexine.

Holotype: Plate 15, fig. 11. NY96C 74C 1165279.

Type locality: Same as species prostata.

Occurrence: Chadakoin Formation (Ellicott Member), Pennsylvania, U.S.A.

Diagnosis: Amb subcircular to oval. Exoexine wrinkled into large radial folds which project at amb. Intexine conformable with amb and laevigate. Laesurae distinct to indistinct.

Description: Miospores radial trilete; amb circular to subcircular to convexly triangular, periphery smooth to undulant. Exine two layered; intexine virtually laevigate up to 2μ m in thickness and distinct; intexine attached to exoexine over proximal surface. Exoexine thin, finely infrapunctate; often with relatively large-scale folds emanating radially from equatorial region. Trilete mark distinct, sometimes obscured by folding; laesurae (where visible) straight extending to almost body radius, simple or associated with folds.

Size range: Exoexine 80-120μ m, mean 92μ m; intexine 60-77μ m, mean 69μ m (35 specimens measured).

Remarks and Comparison: A. prostata is comparable rather than identical with A. prostata sp. nov. var. elongata and differs from the latter by having small folds. Kedo (1976, Pers. Comm.) could not find identical specimens and suggested a new form.

Auroraspora prostata sp. nov. var. prostata var. nov.

Plate 15, figs. 13-14

Holotype: Plate 15, fig. 13. NY96C 69 1172331.

Type locality: Same as species prostata.

Occurrence: Chadakoin Formation (Ellicott Member) Pennsylvania, U.S.A.

Diagnosis: Suboircular pseudosaccate miospores, exoexine wrinkled into sinuous folds which are closely appressed to one another, laesurae straight, simple or accompanied by folds.

Description: Miospores radial trilete; amb circular to subcircular to convexly triangular, periphery entire to irregularly undulating.

Exine two layered; intexine circular to oval in outline, virtually laevigate, and 1-2μ m in thickness; intexine attached to exoexine over proximal surface only, concentric compression folds characteristically developed along periphery of intexine. Exoexine laevigate to infrapunctate with numerous, sinuous wrinkles which are closely appressed to one another. Trilete mark distinct, to hardly discernible, laesurae straight, simple or accompanied by folds, suturae extending to full body radius.

Size range: Exoexine 70-80μ m, mean 76μ m; intexine 50-60μ m, mean 55μ m (30 specimens measured).

Remarks: A. prostata sp. nov. and varieties are stratigraphically restricted to the Chadakoin Formation. The first appearance of these forms is used to define the base of PL zone in the present study.

Auroraspora pseudocrista sp. nov.

Plate 16, figs. 1-10

Derivation of name: Greek, pseudo, meaning lie (false), and Latin, crista, meaning, ridge, tuft, referring to general appearance of the miospores.

Holotype: Plate 16, fig. 1, US9 363 1142592.

Type locality: Cherry Creek, Chautauqua County, New York State, U.S.A.

Occurrence: Present in all four of the formations investigated; New York State and Pennsylvania, U.S.A.

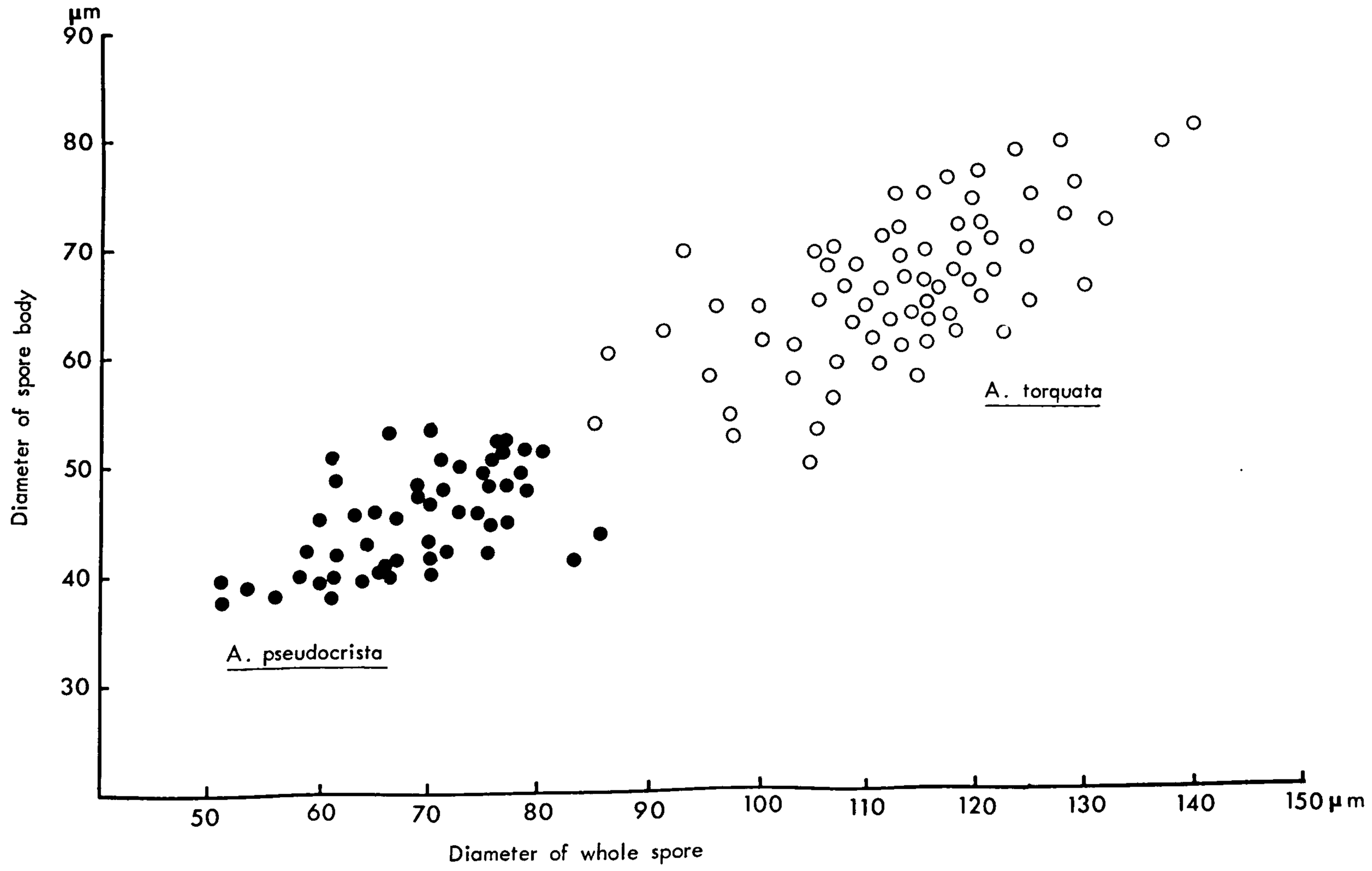
Diagnosis: Subcircular to triangular miospores with rounded triangular intexine, which is covered by thin exoexine; folds usually present on radial region of the exoexine; distance from body radius to pseudosaccus more at angles than in inter-radial areas; laesurae straight or slightly sinuous, extending ½ to full body radius, normally masked by folds.

Description: Miospores radial trilete; amb triangular or subtriangular with straight and convex sides and rounded apices; periphery smooth or slightly undulant. Exine double layered; intexine circular subcircular to rarely subtriangular, 2-3μ m thick, laevigate or distally decorated with muriform elements, 0.5-1.5μ m wide, covered by exoexine and attached to it over proximal surface; a dark area (band) 3-5μ m wide around the equator of the intexine usually discernible. Pseudosaccus (exoexine) 1-1.5μ m thick, laevigate to finely infrapunctate, sometimes appearing shagrinate which may be the result of corrosion pitting. Exoexine narrowest at interradial sides and much wider at angles, where characteristic patterns of folding normally developed (plate 16, figs. 9-10), folds 7-15μ m wide. Specimens usually preserved in proximo-distal compressions. Trilete mark distinct; laesurae straight to slightly sinuous, frequently associated with lips which may simulate exinal folds up to 3μ m high, suturae reaching $\frac{3}{4}$ to full body radius and usually represented by folds beyond it.

Size range: Exoexine 51-87μ m, mean 69μ m; intexine 38-53μ m, mean 44μ m (45 specimens measured).

Remarks: The considerable morphological variations among specimens included in the above category will be evident from the description and supporting plate illustrations. Distal muriform ornamentation on the intexine differs in density from specimen to specimen ; in some cases this feature is sharply defined while in others it could easily be overlooked. As this is not a constant character of the species, the writer does not consider its presence or absence to be an important systematic feature.

Some of the representatives of the present species display extensive damage apparently caused by pyrite crystals (Plate 16, fig. 9). This seems most likely to have been a mechanical effect



Text fig. 6.8. A comparison of size variation in the two species of Auroraspora.

produced by the formation of cubic pyrite crystals before consolidation of the matrix had taken place.

Comparison: Although being structurally similar, A. pseudocrista sp. nov. and A. torquata Higgs, can be differentiated from each other without difficulty as the latter possesses concentric compression folds along the periphery of the intexine and lacks distinctively developed radial folds on the pseudosaccus. Moreover, the Irish form is significantly larger. In order to keep these two species apart, a comparison of the size ranges has been plotted in text fig. 6.8.

Auroraspora solisorta Hoffmeister, Staplin & Malloy 1955

Plate 17, fig. 1

1955 Auroraspora solisortus Hoffmeister, Staplin & Malloy p. 381, pl. 37, fig. 3.

Occurrence: Canadaway, Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Size range: Exoexine 60–70μ m, mean 66μ m; intexine 20–30μ m, mean 24μ m (30 specimens measured).

Remarks: The specimens observed during the present investigation, agree significantly with those described by Hoffmeister, Staplin & Malloy from Mississippian of Kentucky, U.S.A. Pseudosaccus, in the present form, is extremely thin, 1μ m or less and it exhibits infrapunctations and fine folds. Laesurae tend to be simple, attain body radius or nearly so.

Auroraspora submirabilis (Luber) comb. nov.

Plate 17, figs. 2-3

1963 Hymenozonotriletes submirabilis (Luber) Jush. in litt. in Kedo pl. 6, figs. 135-137.

Occurrence: Rare. Canadaway, Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Description: Miospores radial trilete; amb and body outline subcircular to subtriangular, margin entire to slightly undulating. Exine two layered, intexine thick virtually laevigate, covered by exoexine and attached to it over proximal surface. Exoexine 1-1.5μm thick, laevigate, with finely wrinkled surface. Trilete mark distinct; laesurae straight, simple, extending $\frac{1}{2}$ to full body radius, rarely accompanied by folds.

Size range: Exoexine 51-90μm, mean 70μm; intexine 40-70μm, mean 51μm (70 specimens measured).

Remarks and Comparison: Specimens described above bear close morphographic similarities with those figured and described by Kedo (1963). Auroraspora macra Sullivan (1968) described from the Tournaisian of Scotland seems to be similar to the Russian species. The Scottish form may be distinct in having a smaller size range (46-68μm).

Auroraspora torquata Higgs

Plate 17, figs. 4-5

1975 Auroraspora torquata Higgs, p. 338, pl. 4, figs. 1-3.

Occurrence: Frequently observed in all the four formations investigated, New York State and Pennsylvania, U.S.A.

Description: See diagnosis in Higgs 1975, p. 338.

Size range: Exoexine 85-140μm, mean 115μm; intexine 50-81μm, mean 65μm (70 specimens measured).

Remarks: Higgs (1975 p. 398) interprets the exoexine as being granulate. The specimens of A. torquata recorded during the present investigation appear to have laevigate exoexine, but the examination of the holotype would be necessary to establish conclusively the nature of the pseudosaccus.

Auroraspora varia (Naumova) comb. nov.

Plate 17, figs. 6-8

1953 Hymenozonotriletes varius Naumova p. 25, pl. 4, fig. 1.

1953 Hymenozonotriletes varius Naurova var. minor Naumova p. 85, pl. 18, figs. 26-27.

1957 Hymenozonotriletes varius Naumova in Kedo, p. 29, pl. 2, fig. 5.

Occurrence: Canadaway, Chadakoin and Cattaraugus Formation, New York State and Pennsylvania, U.S.A.

Description: Miospores radial trilete; amb circular to oval, periphery smooth to irregularly undulating. Exine two layered; intexine corresponding with the spore outline in shape, laevigate, distinct, and up to 2μm in thickness: intexine attached to exoexine over proximal surface. Exoexine thin, finely infrapunctate and occasionally wrinkled into small folds. Trilete mark distinct; laesurae straight, simple or accompanied by folds; suturae extending $\frac{1}{2}$, $\frac{3}{4}$ to full body radius.

Size range: Exoexine 68.8-97μm, mean 84μm; intexine 45.9-61.2μm, mean 52μm; ratio of body to pseudosaccus 63-88% (35 specimens measured).

Remarks and Comparison: A. varia in Naumova 1953 has a size range of 80-85μm and A. varia var. minor has a size range of 30-35μm. Some of the specimens of A. varia are of an intermediate size (also see Kedo 1957) which indicates the possibility of the two forms merging rather than being separated by a gap in the size range. Kedo concurs with the author in assigning the present form to A. varia (Kedo pers. comn. 1976). A specimen labelled Hymenozonotriletes commutatus in Higgs (1975, pl. 5, fig. 12) from the Upper Devonian of Ireland could be attributable to A. varia (Naumova) comb. nov.

Auroraspora varia (Naumova) comb. nov. var. multifaria var. nov.

Plate 17, figs. 9-10; Plate 18, fig. 1

Derivation of name: Latin, multifarius, meaning manifolds, referring to various folds covering the miospores.

Occurrence: Chadakoin and Cattaraugus Formations, New York State and Pennsylvania, U.S.A.

Diagnosis: Amb subcircular to oval; exoexine with numerous large-scale, sinuous folds; intexine usually indistinct; laesurae indiscernible.

Description: Miospores radial trilete; amb subcircular, convexly triangular to oval, periphery smooth but sometimes distorted by folds. Exine two layered; intexine more or less conformable in outline with amb, usually indistinct. Exoexine laevigate to infrapunctate with relatively large-scale, randomly dispersed, sinuous folds. Trilete mark usually obscured by the folding; laesurae, where visible, simple or accompanied by folds; suturae extending $\frac{1}{2}$ to $\frac{3}{4}$ of body radius.

Size range: Exoexine 60-80 μm, mean 72 μm; intexine 41-62 μm, mean 54 μm (30 specimens measured).

Remarks and Comparison: The present form is usually found occurring in sporangial masses i.e. a cluster of specimens (from two to more than two). It is conceivable that the spores of A. varia var. multifaria stand a better chance of being preserved as fossils than the parent species. Hymenozonotriletes rugosus Naumova (1953, pl. 17, fig. 16) is probably a labrate form which may prove to be conspecific with A. varia var. multifaria, but this could only be established conclusively by an examination of the holotype.

Auroraspora versabilis (Kedo) Turnau 1975

Plate 18, fig. 2

1957 Hymenozonotriletes versabilis Kedo p. 36, pl. 3, fig. 4.

1974 Rugospora versabilis (Kedo) Streel in Becker et al. p. 27, pl. 21, figs. 2-5.

1975 Auroraspora versabilis (Kedo) Turnau p. 516, pl. 5, fig. 7.

Occurrence: Chadakoin and Cattaraugus Formations; New York State and Pennsylvania, U.S.A.

Description: See Turnau 1975, p. 516.

Size range: Exoexine 63.7-90 µm, mean 76 µm; intexine 35.7-60 µm, mean 48 µm; ratio of body to pseudosaccus 55-66% (32 specimens measured).

Remarks: The species is distinct in having characteristic folds emanating radially from polar region which project at the amb. Streel's (in Becker et al. 1974, pl. 21, fig. 2) specimen labelled Rugospora versabilis is similar in construction to A. commutata. A comparison of body pseudosaccus ratio between A. versabilis and A. prostata is plotted on text fig. 6.7.

Auroraspora sp.

Plate 18, fig. 3

Occurrence: Chadakoin Formation, Ellicott Member, New York State, U.S.A.

Description: Miospore radial trilete; amb and body outline subcircular to subtriangular, periphery smooth to slightly undulant. Intexine eccentrically placed, virtually laevigate, and up to 2 µm thick. Exoexine laevigate to infrapunctate. Trilete mark distinct; laesurae straight, accompanied and frequently masked by lips or folds, 5µ m wide, suturae extending to body radius.

Size range: Exoexine 38.2-45μ m; intexine 32-40μ m (5 specimens measured).

Remarks and Comparison: As only a few specimens are observed, no specific assignation is attempted. A closely comparable category seems to be A. pallida but the latter is distinct in having a thinner pseudosaccus and simple laesurae. Hymenozonotriletes truncatus Naumova in Kedo 1957 may be conspecific to the present form.

MORPHOLOGICAL TRENDS IN THE GENUS AURORASPORA.

Distinctive patterns of folding, developed to varying degrees on different forms of the genus Auroraspora, result in a morphological series. Some species of Auroraspora recorded during the present investigation have, therefore, been grouped into three complexes, controlled not only by stratigraphical intervals, but also morphological variations. It will be evident from studying text fig. 6.9. that there is a gradual change in morphology from the base of the section to a point almost at the top of the strata investigated. It is also rather interesting to note that these tentative and maybe endemic morphological variants coincide to some extent, in terms of numbers and characters of species, with miospore zonations established during the present work.

As mentioned above, three Auroraspora complexes have been established during the present investigation. These are in ascending stratigraphical order as follows.

I. Auroraspora pseudocrista complex.

2. Auroraspora solisorta complex.

3. Auroraspora commutata complex.

Each complex, characterised by particular forms possessing distinctive morphological features, is discussed below.

FORMATIONS | MEMBERS | MIOSPORE ZONES | SAMPLES NO

CATTARAUGUS | UNDIFFERENTIATED | VALLATISPORITES VALLATUS VAR. HYSTRICOSUS - RETISPORA LEPIDOPHYTA

US7
NY95A
US6H
US6E
US6D
US6A
US8C
NY96H
NY96B
NY96A

CHADAKOIN

DEXTERVILLE | SYNORISPORITES FLEXUOSUS - AURORASPORA VARIA

US4F
US4D
US4B

CANADAWAY | NORTHEAST

US10A

JAVA | PIPE CREEK | STREELISPORA CATINATA / ANCYROSPORA NEOGRANDISPINOSA

US11B
US11A

NY95C

A.multifaria
US6E

US6A
A.versabilis
NY96C-US6A

NY95A
US6G
A.varia var. multifaria
NY96C-US6G

NY96H

A.cf.papillara
NY96A-NY96B

A.papillara
NY96A-NY96B

A. prostata
NY96A-NY96H

A. prostata var elongata
NY96A - NY96H

A. prostata var. prostata
NY96A - NY96H

A.callosa
US4F-US8C

A.poljessica
US4F-Ny95C

A.commutata var. major
US4D - NY96H

A.micromanifesta
US4B - US6H

A.solisorta
US10A-US7

A.submirabilis
US10A - US6H

A.pallida
US10A-US7

A.varia
US10A-NY95A

A.pseudocrista
US11A-US6D

A.torquata
US11B-NY95A

TEXT FIG 6 9 DIAGRAMMATIC SKETCHES ILLUSTRATING THE MORPHOLOGICAL VARIATIONS IN DIFFERENT SPECIES OF THE GENUS AURORASPORA THE SPECIES ARE ARRANGED (FROM BOTTOM TO TOP) IN THEIR APPROXIMATE ORDER OF APPEARANCE IN THE UPPER DEVONIAN OF NEW YORK STATE AND PENNSYLVANIA, U S.A

I. Auroraspora pseudocrista Complex: In this complex large distinctive forms such as A. pseudocrista and A. torquata have been observed. These species range throughout the sequence and occur in the lowermost samples studied (Java Formation). A. pseudocrista ranges from samples USIIA to US6D, whilst A. torquata has been found occurring from samples USIIB to NY95A (see Text fig. 6.9.). A comparison of both species lends some support to the view that A. pseudocrista is morphologically related to A. torquata. However, their relationship is indicated by a question mark because the two species have quite different size ranges (see Text fig. 6.8.).

This complex is distinguished by the species possessing large folds on the pseudosaccus and/or the inner body. Also at this horizon forms having a size less than 51μm have not been encountered. Finally, it is important to emphasize that this assemblage has only been recognized in the CN zone described in this work and at highers these species are accompanied by other species of Auroraspora.

2.Auroraspora solisorta Complex: The second group of Auroraspora species makes its stratigraphical debut at the base of the FV zone. Five miospore species have been recorded in this complex. The species occurring within this horizon are illustrated in text fig. 6.9.

A small species having its pseudosaccus slightly larger than its inner body e.g. A. pallida, and another miospore species possessing an extremely thin pseudosaccus e.g. A. solisorta, have been recorded from the Upper Canadaway Formation (USIOA) up to the top of the sequence (US7). A. varia also bears a thin walled pseudosaccus and is recorded from the Canadaway to Cattaraugus Formations (USIOA to NY95A).

Another species, A. submirabilis originally described from the Soviet Union which possesses a finely infrapunctate, probably corroded pseudosaccus. This species has been recorded from the Upper Canadaway to Cattaraugus Formations (USIOA to US6H). At a slightly higher level, US4B, Chadakoin Formation, one specimen of the Canadian species A. micr-

omanifesta has been recorded, while another specimen of identical form has been found occurring still higher in the sequence, at US6H. Both of these specimens are illustrated on pl. I4, figs. 8-9.

In all of these forms of the complex the pseudosaccus is finely and simply folded. The size of the species in this assemblage ranges from 29μ m to I00μ m.

3. Auroraspora commutata Complex: This complex begins in the upper part of the FV zone and within the Dexterville Member. It is characterised by species of the genus Auroraspora which possess a characteristic pattern of folding. The incoming of such distinctively folded and wrinkled forms warrants the recognition of this complex.

It appears that these forms are genuine morphological variations of A. commutata. A. commutata is the first species to occur at the base of this FV assemblage showing radial folds. This has been recorded from the Chadakoin (Dexterville and Ellicott Members) Formation (US4D to NY96H). Some larger specimens corresponding to var. major have also been encountered.

It is believed that A. callosa bears possibly close morphological relationship to A. solisorta. The two miospores are almost identical morphologically, however A. callosa possesses a compressionally folded body whilst A. solisorta has an unfolded body. A. callosa has been recorded from the Chadakoin Formation (US4F to US8C).

At this stratigraphical interval the incoming of A. poljessica is rather interestering. This species shows minute and closely packed folds and wrinkles all over the pseudosaccus. Because of its comprehensive folds, it is considered premature to attempt to attribute morphologically such a distinctive form to any of the species exhibited and described in this work. The form has been recorded from the Chadakoin and Cattaraugus Formations (US4F to NY95C).

At the base of the HL zone, species possessing radial and projecting folds have frequently been observed. The restricted vertical range of these forms is worthy of special mention. These miospores are confined to the lower part of the Ellicott Member of the Chadakoin Formation (Bush Hill Section). The incoming of these forms together with their vertical range is shown in text fig. 6.9.

At a slightly higher stratigraphical level a miospore with well defined radial folds, A. versabilis, was recorded from the Chadakoin and Cattaraugus Formations (NY96C to US6A).

It is important to note that intensively folded rather damaged miospores have frequently been found occurring in clusters. These have been recorded from the Chadakoin and Cattaraugus Formations (NY96C to US6G). The author regards these species to be gradational form of A. varia.

Finally, almost at the top of the sequence another miospore species A. multirugata with numerous sinuous wrinkles on the pseudosaccus was encountered in sample US6E.

Text fig. 6.9. indicates the morphological variations of specimens of the genus Auroraspora, encountered in the samples investigated and arranged stratigraphically together in relation to the three miospore zones established during the present study. Due to lack of space not all the samples could be illustrated in a particular column. For a complete list of samples arranged stratigraphically and sections investigated, the readers are referred to the text figs. I.2. and 7.3.

INCERTAE SEDID

Genus ANCYROSPORA Richardson I960 emend. Richardson I962

Type species: A. grandispinosa Richardson I960

Diagnosis: See Richardson I962, p. I75.

Remarks: Urban (I969) provided an adequate appreciation of morphology of the genus Ancyrospora by studying two species under SEM. He observed that processes are formed by the fusion of "elongated bars of netlike inner exoexine". However, these results are additional informations of the exinal layers which are useful at specific level but not to modify the genus. Generic diagnosis given by Richardson (I962) is quite comprehensive and still remains the basic circumscription of this taxon, hence followed in the present work.

Ancyrospora acadensis sp. nov.

Plate 18, figs. 4-9

Derivation of name: Acadia, old name of the eastern part of North America.

Holotype: Plate 18, figs. 4-5, US6E 299 1125055.

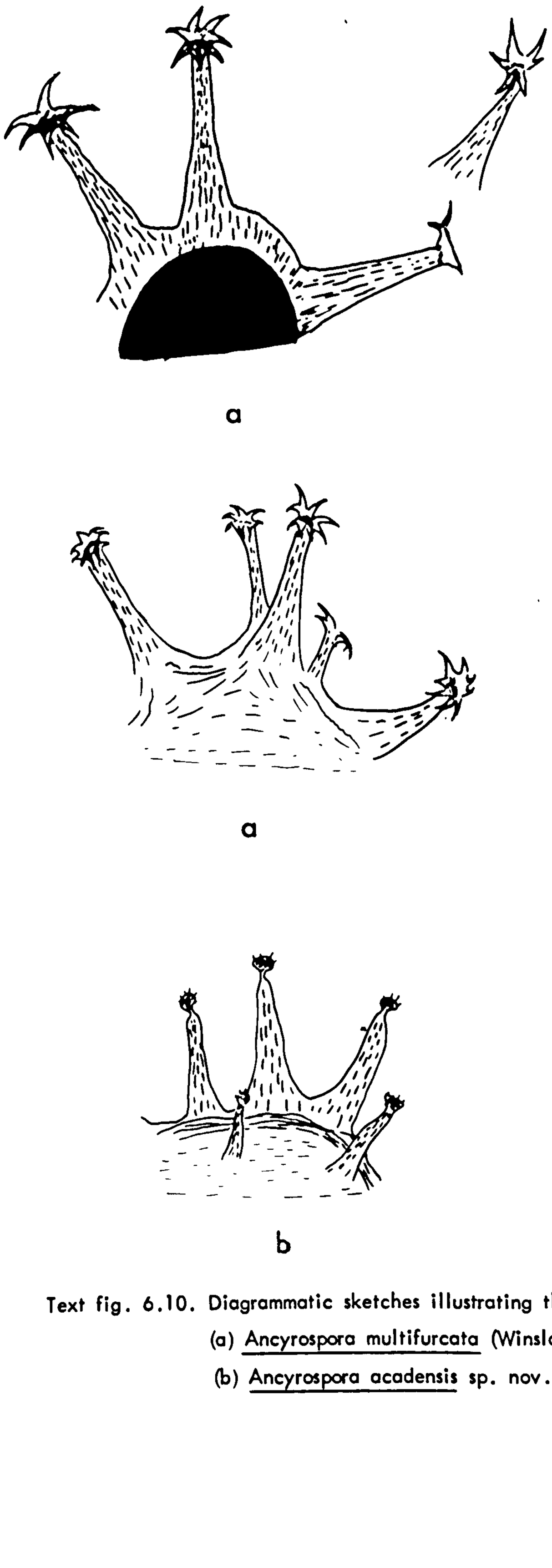
Type Locality: Pope Hollow Section, along boundary between Carroll and South Vally Townships, Jamestown quadrangle, New York State, U.S.A.

Occurrence: Present in all four of the formations investigated.

Diagnosis: Amb subcircular to roughly hexagonal; exoexine completely appressed to the intexine. Distal and equatorial margins bear spines with a constriction near the top; spines are usually terminated by multifurcate terminations. Laesurae discernible, simple or masked by folds.

Description: Miospores radial trilete; amb irregular due to the distribution of conical bases of appendages but in general organization subtriangular to roughly hexagonal. Exine two layered; the intexine laevigate, with/a distinct or indistinct margin and the exoexine which is closely appressed to it and extends equatorially to form a narrow flange or pseudoflange. Distal and equatorial hemispheres ornamented by processes 8-28μm long, 4-12μm broad at the base, slightly curved occasionally straight with a constriction near the top. Each process consists of a broad-based spine with moderate to sharply tapering sides terminated by a narrow, slightly expanded, solid, bi, tri- or multifurcate termination (see text fig. 6. IO, pl. 18, fig. 5). Trilete mark distinct, sometimes obscured by thick nature of exoexine; laesurae straight extending $\frac{3}{4}$ to the full spore radius. Folds occur along the tetrad mark which extend to the radius of the spore.

Size range: 38-71μm, mean 61μm (70 specimens measured).



a

a

b

Text fig. 6.10. Diagrammatic sketches illustrating the nature of spines in (a) Ancyrospora multifurcata (Winslow) comb. nov.; and (b) Ancyrospora acadensis sp. nov. Lateral views.

Comparison: Ancyrospora densispinosa Bharadwaj et al. (1971) described from the Upper Devonian of Kentucky, appears comparable to this species, but it lacks constriction and multifurcate terminations to the processes.

Ancyrospora ancyrea (Eisenack) Richardson var. ancyrea Richardson 1962

Plate 18, fig. 10

1925 Type G2 Lang p. 257, pl. 1, figs. 16-17.

1944 Triletes ancyreus Eisenack p. 110 (part), pl. 2, fig. 2; pl. 1, figs. 7-8.

1962 Ancyrospora ancyrea (Eisenack) Richardson var. ancyrea Richardson 1962.

?1966 Ancyrospora sp. cf. A. ancyrea (Eisenack) Richardson; De Jersey p. 20, pl. 8, figs. 9-12.

Occurrence: Present in all four of the formations studied.

Diagnosis: See Richardson 1962, p. 177.

Size range: Exoexine 61-153µm, mean 102µm; intexine 48-79µm, mean 61µm (30 specimens measured). Spine length 10-35µm, basal width 7-10µm.

Remarks: The specimens from New York State and Pennsylvania, although corroded, appear to be similar to specimens of A. ancyrea var. ancyrea from the Orcadian Basin, Scotland.

Ancyrospora multifurcata (Winslow) comb. nov.

Plate 18, fig. 11; Plate 19, figs. 1-4

1962 Dicrospora multifurcata Winslow in part Mortimer & Chaloner p. 53, pl. 12, figs. 8 & 8b; Pl. 13, figs. 1&6, 7-9.

1962 Dicrospora multifurcata var. impensa Winslow, p. 54, pl. 12, figs. 7, 7a.

1970 Ancyrospora ? capillata Dolby & Neves, p. 639, pl. 2, figs. 7-10.

Occurrence: Present in all four of the formations studied.

Description: Micospores radial, trilete; amb subcircular, subtriangular but normally irregular because of the distribution of wide bases to the spines. Proximo-distal compression rare, oblique and lateral views frequent. Broken specimens common. Exine two layered; exoexine completely covers the thick walled subcircular to irregular laevigate body, attached proximally and distally. Ornamented by spines, 2I to 5Iμ m in length, some of these gradually taper towards the top while others nearly cylindrical with wide conical to bulbous bases. Spines as wide as 23μ m at the base to 2.5μ m near top. Number of spines vary from 9 to 23 on the equatorial and distal surfaces; nearly half the total are mounted distally. At the top spines are multifurcate comprising 2 to 9 hook like spinules, 2.6 to I0.2μ m in individual length while the total diameter of terminal processes range II to 24.4μ m. On some specimens the multifurcate processes are laterally extended, expanded and reflexed. Trilete mark indistinct due to the dark and dense nature of intexine.

Size range: Exoexine 83.8-I53μ m, mean I05μ m; intexine 5I-89.3μ m, mean 70μ m (55 specimens measured).

Remarks and comparison: Ancyrospora multifurcata is identical to both Dicrospora multifurcata Winslow (I962) and D. multifurcata var. impensa Winslow (I962) except for size, which is regarded as insufficient justification to differentiate these two forms. Winslow (loc. cit.) gave a size range of I00-200μ m in the diagnosis of D. multifurcata and 240-300μ m for D. multifurcata var. impensa. The second basis for differentiation which she mentioned is the presence of both bi - and multifurcate appendages on D. multifurcata var. impensa but only multifurcate spines on the parent species. It has been observed during the present investigation that both kinds of appendages are present on a single specimen, so there is no reason for varietal separation.

Mortimer & Chaloner (1967) justify keeping all the species of Dicrospora within the morphographic circumscription of Hystricosporites McGregor. However, it is felt that the spores described here have characteristics typical of Ancyrospora. Winslow (1962) did not mention the presence of inner body in her specimens but it is obvious from the figures that some of the specimens possess intexine.

It is further suggested that Dolby & Neves's spores labelled Ancyrospora ? capillata are certainly identical to the present form. The species name capillata has been discarded because Winslow's specific epithet has priority.

Grandispinosa multiapicalis Chi & Hills is probably identical to A. multifurcata.

Ancyrospora neograndispinosa sp. nov.

Plate 19, figs. 5-6

Derivation of name: A species of Ancyrospora similar to A. grandispinosa .

Holotype: Plate 19, fig. 5, USGD 355 1130327.

Type locality: One mile south of Hamlet town, New York State; Ellicott Member of Chadakoin Formation.

Occurrence: Frequent in the Java and Canadaway Formations, rare in the Chadakoin and Cattaraugus Formation

Diagnosis: Miospores two layered, comprising a well-defined inner body completely covered by thin exoexine; the latter is ornamented by well-developed appendages including gently tapering spines and cones which frequently bifurcate at their terminations; exoexine irregular in outline; laesurae frequently masked by folds.

Description: Miospores radial trilete; amb irregular, occasionally subtriangular with straight to convex sides and rounded apices. Exine double layered; the intexine subcircular, thick, laevigate

and the exoexine which is closely appressed to it and extends equatorially to form a flange or pseudoflange. The width of the exoexine from intexine equal to subequal, in a few cases more at angles than at interradial areas. Exoexine thin, finely infrapunctate, ornamented equatorially and distally by hollow cones and spines, the former 5-15μ m long and 3-10μ m wide at bases, spines vary in length from 10-35 m and in basal width from 5-10, Elements taper gently throughout their length, some are parallel sided while a few taper for only ½ of their length to a slender neck, terminated by bifurcate tips. Number of spines along equator 6-17. The appendages on the distal surface are coalesced at their bases;

spines normally stout rarely curved. Trilete mark distinct; laesurae indiscernible to perceptible, folds on the suturae run beyond the body but do not reach to the equator of the spore.

Size range: 87-130μ m, mean 109μ m; intexine 56-80μ m, mean 68μ m (30 specimens measured).

Comparison: Ancyrospora grandispinosa Richardson(1960) stands closest morphologically but differs however, in possessing spines with wide conical bases. The Scottish form lacks conical processes and it is also considerably larger (174-276μm). A. confluenca Tiwari & Schaarschmidt (1975) described from the Middle Devonian of the Prüm Syncline, Eifel (Germany), is closely similar but differs from A. neograndispinosa in not having well defined spines.

Spore Type

Plate 20, fig. 6.

Occurrence: Cattaraugus Formation, New York State, U.S.A.

Description: Radial trilete miospore of subtriangular amb; sides slightly convex with rounded apices. Specimen variously folded and owing to distinctive folds in the central area it is difficult to affirm or deny the possible presence of darkened contact areas. Trilete mark distinct;

laesurae frequently associated with folds which extend, decreasing in height and width, to almost equator of the spore.

Size range: Only one specimen, measuring 52μ m.

Remarks and comparison: This form shows closest resemblance to the "Spore type E" of Hoffmeister, Staplin & Malloy (1955, p. 398, pl. 39, fig. 8) from the Upper Mississippian of Kentucky, but differs in shape characteristics, as well as its smaller size (38μm) and longer trilete rays. Spore type E of Hoffmeister et al. is deltoid in outline.

CHAPTER 7

BIOSTRATIGRAPHY AND COMPARISON OF THE SECTIONS STUDIED

BIOSTRATIGRAPHY AND DESCRIPTION OF MIOSPORE ASSEMBLAGES

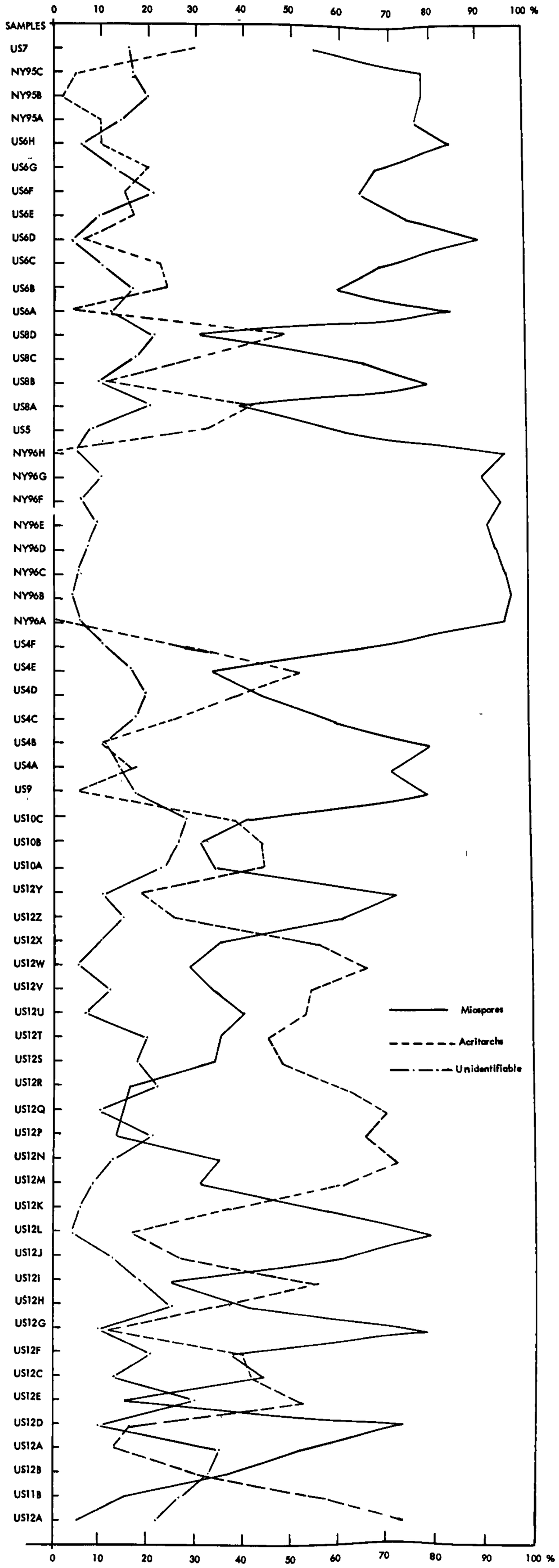
Most palaeopalynological studies have an initial goal of biostratigraphical zonation. This is because the need for stratigraphical control in exploration for petroleum, coal, water and sedimentary mineral deposits has provided an incentive for such investigations. The application of palynology to strati-graphical problems has been described in detail by several workers e.g. Couper (1958), Pocock (1962), Smith & Butterworth (1967), and has been reviewed by Tschudy (in Tschudy & Scott 1969). Smith & Butterworth (loc. cit.) conclude that for stratigraphical and correlation purposes fossil spores are invaluable. These authors further suggest that sometimes miospores are the only source of evidence when macrofossils are largely destroyed by drilling techniques and where palynomorphs commonly occur in abundance (several thousand per gram of sample).

In defining miospore assemblage zones in the Upper Devonian system of New York State and Pennsylvania qualitative data have been expressed as ranges of key species. On the other hand quantitative counts are very useful in local or interbasinal correlations where dominant floras may fluctuate with ecological factors such as climatic and edaphic changes, even though no evolutionary changes can be recognized. This has been demonstrated under the heading 'Comparative palynology of the Bush Hill and Pope Hollow Sections, (See p.230).

The stratigraphical distribution of miospore species from all four formations is plotted in table 7.1 . Three distinctive miospore assemblage zones can be determined. One from the Java, the second from Canadaway and thirdly from Chadakoin Formation.

No distinctive miospore species were encountered in the Cattaraugus Formation to warrant a separate zone. Plant microfossils in the area studied show a gradual increase (in number) and, therefore, biostratigraphical zonation is based on the concurrent ranges of species, using the first appearance of species (rather than extinction) to define the zone boundaries. Key species are morphologically distinctive and reasonably common, with restricted ranges. Such zones are valuable for interbasinal and intercontinental correlations. Allowances have to be made, however, for the influence of local environments on the distribution of any particular species from a given area. It is worthy of mention that the index fossils of the third or HL assemblage zone have substantial geographical extent and have proved to be excellent markers in defining Devonian-Carboniferous boundary (Fa2d/Tn1). The lower limit of the R. lepidophyta marks the Fa2c/2d boundary within the upper Famennian (Streel, 1970, p. 122).

Aneurospora greggsii is the most numerous component in some of the samples of the present study. This is especially true in sequences in the Lower part of the Ellicott Member of the Chadakoin Formation where the proportion of A. greggsii ranges from 30 to 43.5%. In the assemblage of the overlying Cattaraugus Formation this taxon declines in abundance to only 1% or less of the total assemblage. This oscillation is clearly facies controlled. The species shows its peak in the continental strata e.g. Bush Hill Section, while in marine facies it is reduced. It is of interest to note that the occurrence of acritarchs is surprisingly erratic. As will be evident from text fig. 7.I. at certain levels these are invariably subordinate while at others numerically dominant to the associated miospores. Text fig. 7.I. also shows percentage distribution of miospores, acritarchs,



Text fig. 7.1. Percentage distribution of miospores, acritarchs and unidentifiable in the samples investigated.

and unidentifiable palynomorphs in the samples investigated.

All of the miospore forms examined during the course of the present investigations are trilete. The exine of the miospores exhibits a variety of constructional modes including smooth laevigate, cingulate, zonate and pseudosaccate forms. Apart from miospores exhibiting retusotrilete structure, sculptured forms that were observed during the present study include granulate, spinose, apiculate, verrucate, muronate, reticulate and miospores ornamented with terminally furcated appendages. Thus, the miospore assemblages recovered from New York State and Pennsylvania are in line, in broad morphology, with those reported from the equivalent stratigraphical levels elsewhere. Megaspores have also been encountered which were stratigraphically restricted to the lower half of the Ellicott Member (Bush Hill Section). Their occurrence was not unexpected as the host strata were nonmarine. The biostratigraphical framework showing zonation based on macrofossils (Ammonoid , Brachiopod, and Conodont), on the left side of the chart (table 7.I.) is modified from Richard (1975).

After the study of Upper Devonian sediments from New York State and Pennsylvania. Three miospore assemblage zones are proposed and are given below in ascending stratigraphical order:

1. Streelispora catinata - Ancyrospora neograndispinosa (CN) Zone.
2. Synorisporites flexuosus - Auroraspora varia (FV) Zone.
3. Vallatisporites vallatus var. hystricosus - Retispora lepidophyta (HL) Zone.

DESCRIPTION OF MIOSPORE ASSEMBLAGE ZONES:

1. Streelispora catinata - Ancyrospora neograndispinosa (CN) Zone

Concurrent range zone defined by the stratigraphical interval from the lowest occurrence of the index species up to

TABLE 7.1. STRATIGRAPHICAL RANGES OF MIOSPORES, AND ASSEMBLAGE ZONES IN THE UPPER DEVONIAN OF NEW YORK STATE AND PENNSYLVANIA, U.S.A.

ERA	SYSTEM	STAGE	AMMONOID ZONES	CONODONT ZONES	MIOSPORE ZONES	MIOSPORE SERIES	MIOSPORE GROUP	ROCK UNITS FORMATION	ROCK UNITS MEMBER	SAMPLES	SPECIES
EASTERN NORTH AMERICA	DEVONIAN	FAMENNIAN	Cheiloceras subpalmatum	Palmatolepis perlobata	Retispora lepidophyta	CONEWANGO	CATTARAUGUS	UNDIFFERENTIATED	ELLICOTT		
				Palmatolepis marginifera	Vallatisporites vallatus var. hystricosus - Retispora lepidophyta			CHADAKOIN			
				Palmatolepis rhomboidea	Synorisporites tlassaensis - Auroraspora macra			CHAUTAUQUAN	DEXTERVILLE		
				Palmatolepis gracilis sigmoidea	Lophozonotriletes rotundus - Verrucosisporites nitidus			ARKWRIGHT	NORTH EAST SHUMLA WEST FIELD		
				Palmatolepis crepida	Grandispora echinata - Auroraspora asperella			CANADAWAY	LAONA		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella				GOWANDA		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella			SENECA	SOUTH WALES		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella				DUNKIRK		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella			JAVA	HANOVER		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella				PINE CREEK		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella			SENECAN			
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella			UPPER DEVONIAN	CHAUTAUQUAN		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella				ARKWRIGHT		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella				CANADAWAY		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella				SENECA		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella				JAVA		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella				SENECAN		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella				UPPER DEVONIAN		
				Palmatolepis perlobata	Grandispora echinata - Auroraspora asperella			

but not including the lowest occurrence of Synorisporites flexuosus - Auroraspora varia assemblage.

Other distinctive miospores which make their first appearance at the same stratigraphical level include Punctatisporites glaber, P. minutus, Leiotriletes ornatus, Auroraspora torquata and Hystricosporites sp. aff. H. porrectus. Worthy of mention is that these forms persist into both the overlying assemblage zones, ranging up to top of HL zone as seen in the described sections.

There are two distinctive miospore forms whose stratigraphical debut is not known in this area, but range from the base of sequence investigated to the lower part of the Chadakoin formation. These species are Auroraspora pseudocrista sp. nov. and Ancyrospora ancyrea var. ancyrea. Four other taxa appear for the first time at the base of their range in sample US12 B, the base of the Hannover Shale Member of Java Formation. These are Aneurospora greggsii, Emphanisporites rotatus, Samarisporites inusitatus and Ancyrospora multifurcata. Further S. inusitatus appears to be useful, since it is more or less confined to this zone with occasional specimens in the lower part of the overlying assemblage zone. The species E. rotatus appears sporadically in all four formations. The remaining two species occur in many samples throughout the area studied. Aneurspora incohata, Retusotriletes goensis and Grandispora echinula also appear in the Java Formation in sample US12 A. In the middle of the Java formation in sample US12 D, the following species appear for the first time Punctatisporites platirugosus, Apiculiretusispora plicata, Dictyotriletes sp. and Grandispora echinata. All of these forms are sporadically distributed in both proceeding assemblages. Apiculiretusispora plicata has not been found in the Cattaraugus Formation and the form disappears towards the top of the Ellicott Member of Chadakoin Formation or

middle of the HL Zone. Camptotriletes verrucosus and Aneurospora greggsii var. minuta make their first appearance near the base of the Canadaway Formation and the latter persists up to the top of the Cattaraugus Formation. C. verrucosus ranges to the base of the overlying zone and the species may be important as it is restricted to the current zone with only occasional elements confined to the base of proceeding zone. Retusotriletes sp. also appears at the base of the Canadaway Formation. Three species Convolutispora vermiformis, Ambitisporites f. avitus and Streelispora distincta sp. nov. make their stratigraphical debut almost in the middle of the formation. Finally, at the top of the Canadaway Formation Calamospora pedata, Leiotriletes tortilus and Ancyrospora acadensis sp. nov. appear. The species L. tortilus ranges within the top of this (CN) Zone. C. pedata disappears towards the top of the Ellicott Member of Chadakoin Formation while the third species dies out near the top of the Cattaraugus Formation.

The assemblage is diverse in composition, comprising smooth laevigate, cingulate, zonate and pseudosaccate forms plus five species which are sculptured with bi-multifurcate terminations. The average percentage of miospores present in the samples from this zone is 39%, acritarchs are also developed and constitute an average 46% of the total assemblages (see text fig. 7.I.). Also a few specimens of chitinozoans have been encountered, and are confined to this zone. Miospore taxa are comparable, in number, in the CN zone and in the overlying (FV) miospore assemblage zone.

Almost frequent appearance of distinctive pseudosaccate miospore species such as Auroraspora pseudocrista sp. nov. and A. torquata is in general agreement with their expected occurrence in off-shore or marine environment. On the other hand, it is rather

difficult to explain the association of representatives of the taxa Ancyrospora and Hystricosporites in a marine facies. Owen (1971, p. 82) considers that miospores possessing an ornament of heavy processes with forked terminations which would not be suited morphologically to survive in a marine environment. However, such forms are rare and sporadic in occurrence and lack overwhelming representation. The presence of these forms in diverse facies supports Streel's view (1970, p. 49) who has proposed that such forms are amenable to distribution into various depositional environments.

From the material available, the CN Zone differs from overlying assemblages, in a negative sense, as it lacks Synorisporites flexous - Auroraspora varia and Vallatisprites vallatus var. hystricosus - Retispora lepidophyta and their associated forms. No megaspores were encountered in this zone.

2. Synorisporites flexuosus - Auroraspora varia (FV) Zone

This miospore zone is defined as the stratigraphical interval from the lowest occurrence of the index species, up to but not including the first appearance of the V. vallatus var. hystricosus - R. lepidophyta complex.

Other miospore species that make their first appearance simultaneously at this stratigraphic level are simple pseudosaccate forms such as Auroraspora pallida, A. solisorta and A. submirabilis. All of these forms range less consistently in the proceeding HL Zone (see table 7.I.). This zone is also marked by the presence of Samarisporites kedoae, Knoxisporites sp cf. Reticulatisporites crassus, Punctatisporites stabilis, Convolutispora sp, aff. verrucosisporites congestus and P. stabilis. Further Retusotriletes concretus nom. nov. is the last species appearing from top of the Canadaway Formation and persists up to the top of the Cattaraugus Formation.

At the base of the Chadakoin Formation Synorisporites flexuosus (Jušh) comb. nov. is accompanied by another species of the same genus S. variegatus sp. nov. which persist, with some intervals to the top of the overlying formation. Acanthotriletes horridus var. minutus var. nov. is also associated with the crassitudinous form.

The miospore assemblages in this zone show little variation; 6 or 7 taxa make up almost the entire spectrum, and pseudosaccate species are more in number than the underlying assemblage zone (see text fig.6.9.p.193). Accessory species which make their stratigraphical debut from the lower part of the Chadakoin Formation and range to the top of the Cattaraugus Formation include Calamospora nigrata, Retusotriletes caperatus sp. nov; Rhabdosporites parvulus, Calyptosporites perclarus sp. nov. and Grandispora macroseta. The species Rhabdosporites langi has very short range within the lower part of the Chadakoin Formation. Auroraspora micromanifesta has only been encountered at the base of the Chadakoin Formation and higher up in the Cattaraugus Formation. Apiculiretusispora fructicosa and Auroraspora commutata appear at the top of their range in the lower part of the overlying assemblage zone.

No megaspores have been observed in this assemblage.

Acritarchs are quite variable and erratic in appearance (see text fig. 7.I.), contributing 5-51% of the composite population count.

At the top of the current (FV) zone following species appear at the base of their range in sample US4 F; Pulvinispora depressa Acanthotriletes sp. Spelaeotriletes densatus sp. nov. Grandispora corunata, Auroraspora callosa and A. poljessica. With the exception of Auroraspora callosa and Acanthotriletes sp. which do not extend

into the overlying formation, rather disappear towards the middle of overlying zone, the species are less consistently represented and disappear immediately below the top of the HL Zone.

The assemblage has many elements in common with the preceding CN Zone, but is quite distinct in being populated by characteristic forms that make their first appearance here. The assemblage can be distinguished from that overlying it by not possessing V. vallatus var. hystricosus - R. lepidophyta. Further, the absence of these forms in the present assemblage is indicative of older than Upper Famennian (Fa2d) assemblage in age.

3. Vallatisporites vallatus var. hystricosus - Retispora lepidophyta (HL) Zone.

This miospore zone is defined by the stratigraphical interval from the first appearance of distinctive index species.

Both of these forms have an extraordinately wide geographical range and are being used for intercontinental and interbasinal correlation purposes in both the northern and southern hemispheres. Consequently these are now conclusively regarded as exceptionally useful ubiquitous key biostratigraphical markers of the Devonian-Carboniferous boundary, Fa2d (sensu Streel).

Other miospore forms that make their stratigraphical debut at this horizon and range within the lower part of the assemblage are Retusotriletes cf. concinnus, Raistrickia cf. clavata, Auroraspora papillara, A. cf. papillara and Pulvinispora quasilabrata. Further Calamospora liquida, Auroraspora prostara sp. nov., A. prostata var. elongata var. nov. A. prostata var. prostata var. nov. and a spore of megaspore dimension Biharisporites parviornatus disappear towards the top of Chadakoin Formation. In the middle of the Cattaraugus Formation Knoxisporites literatus, K. pristinus

and Convolutispora definata sp. nov. occur at the top of their ranges. Convolutispora mellita and Verrucosisporites maculosus persist with some intervals, up to the top of current zone. V. vallatus var. hystricosus is profusely represented and extends to top of the assemblage with some intervals at the Ellicott Member.

Retispora lepidophyta makes its first appearance in sample NY96B and spasmodically represented to the top of the current zone with an interval in the Ellicott Member of Chadakoin Formation. At the base of the Cattaraugus Formation in sample US6A R. lepidophyta var. granda occurs at the top of its range. Other forms that make their stratigraphical debut in sample 96B are Raistrickia baculosa, Synorisporites richardsonii sp. nov. and L_ophozonotriletes curvatus.

Less consistently represented, but still confined to the HL Zone are Raistrickia ampullacea, Auroraspora versabilis, A. varia var. multifaria var, nov. Dibolisporites sp., Hystricosporites porcatus and H. mitratus. Some accessory species represented by quite a few representatives are listed in table 7.1. Some of those are Spelaeotriletes microverrucosus, Samarisporites sp. cf. S. kedoae, Geminospora lemurata and Dictyotriletes cf. trivialis. All of these forms range within the Ellicot Member of Chadakoin Formation. While Spinozonotriletes sp., Emphanisporites cf. annulatus and Auroraspora multirugata persist within the lower part of the Cattaraugus Formation.

It will be evident from the species range chart and text fig. 6.9 that there is a gradual increase (qualitative as well as quantitative) in the representatives of genus Auroraspora from bottom to top of the miospore assemblages described here. CN Zone is characterised by only two species of Auroraspora while in the overlying FV Zone eight species of the genus are represented. The total number of the species belonging to the genus Auroraspora is nine in the HL Zone.

Consequently nineteen species of Auroraspora have been described and illustrated. Morphological relationship with respect to stratigraphical interval, between various forms of the genus, has been illustrated in text fig. 6.9.

The incoming of Auroraspora prostata sp. nov. and its varieties elongata and prostata appears to be potentially useful and these forms are tentatively used here for a miospore zonation, however their value as marker species appears to be local and probably impart a strongly endemic character.

These forms possess a pattern of coarse radial folding on the pseudosaccus. This character could be a significant factor of continental facies.

The miospore population in the current (HL) zone exhibits considerable diversity including miospores and spores of megaspore dimension. In a broad sense ten or eleven but more precisely only two taxa make up the entire spectrum. A few accessory elements have been encountered with frequencies as low as one specimen per 1,000 counted specimens.

The current (HL) miospore range zone can further be divided into two distinct subzones, (see text fig. 7.1). The lower assemblage represents continental facies, subsequently devoid of acritarchs. The overlying is influenced by marine conditions. Comparison of the miospore assemblages between these two diverse facies has been made in a separate section in this work (see pages 227-40). However, it is appropriate to draw here salient features of these facies controlled assemblages. The lower continental subzone is confined only to the middle part of the Chadakoin Formation or the lower half of the Ellicott Member. This part of the section is distinct qualitatively and to some extent quantitatively. The assemblages recorded from this horizon are in excellent state of

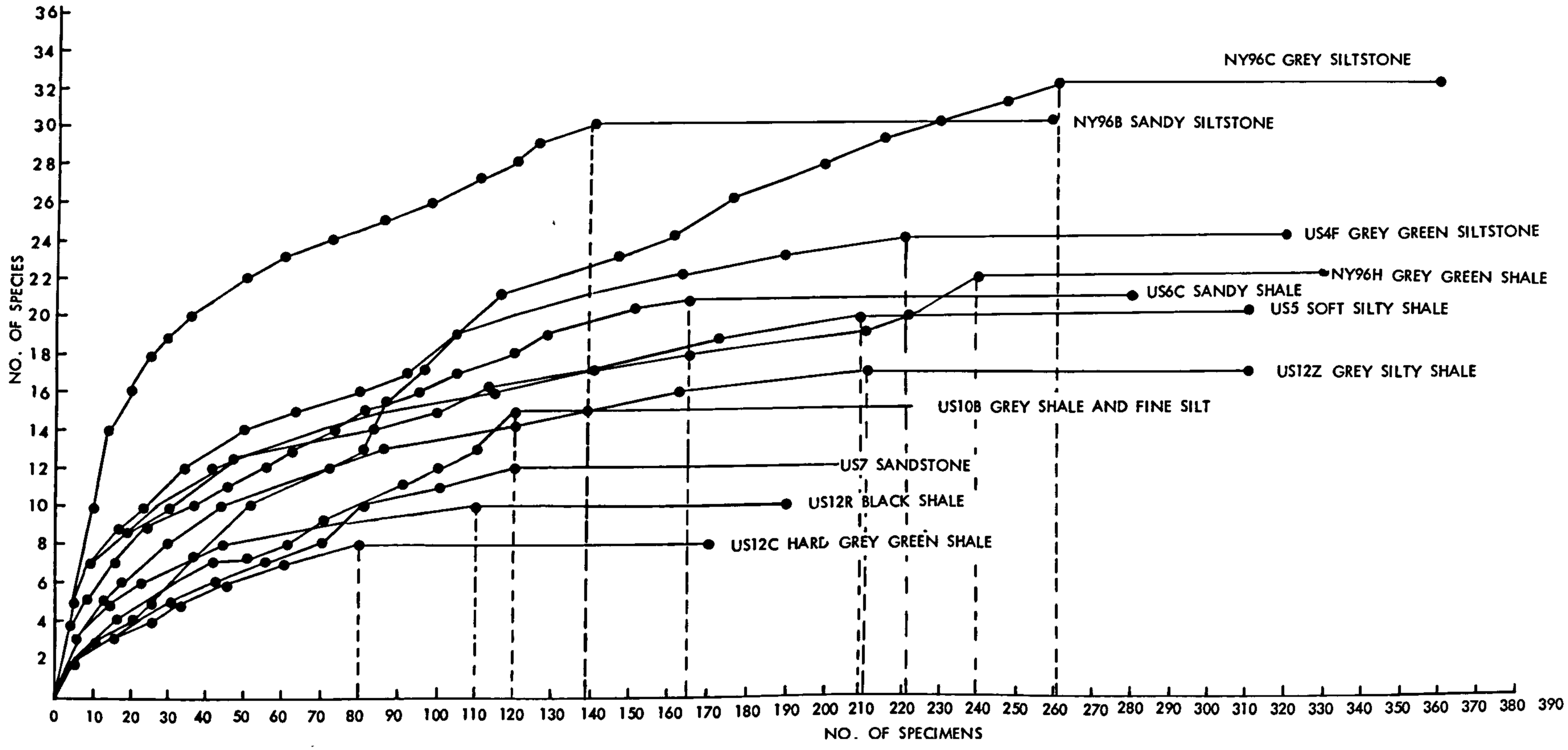
preservation and show considerable diversification.

The overlying subzone ranges from upper part of the Ellicott Member or the upper part of the Chadakoin Formation to the top of the Cattaraugus Formation. (On stratigraphical column it is indicated from sample US5 through sample US7). Miospores average 67% in contrast to 94% in the preceding subzone.

Taking into account the average percentage ratio of miospores and acritarchs, this part of the section i.e. sample US5 to US7 can again be divided into two parts. The boundary may lie somewhere between samples US8D and US6A i.e. the boundary of the Chadakoin and Cattaraugus Formations (see text fig. 7.1.). The average percentage of miospores in the lower part is 54%, acritarchs 32%. In the overlying horizon miospores average 73% and acritarch 13.6%. As is obvious there is clear inverse relationship between miospores and acritarchs in the upper most part of the section investigated.

The HL Zone has many elements in common with the preceding FV Zone but is recognized in a positive sense by containing additional species discussed above. In particular the incoming of V. vallatus var. hystricosus and R. lepidophyta is a widespread biological event.

From the sequences in New York State and Pennsylvania the quantitative data have been plotted on text fig. 7.2. which shows that palynological assemblages from the Java (US12C) and middle part of the Canadaway (U12R, UD12Z) Formations have predominance of individuals of a few species; while assemblage from top of the Canadaway Formation (US10B) have many species with relatively a few individuals of each.



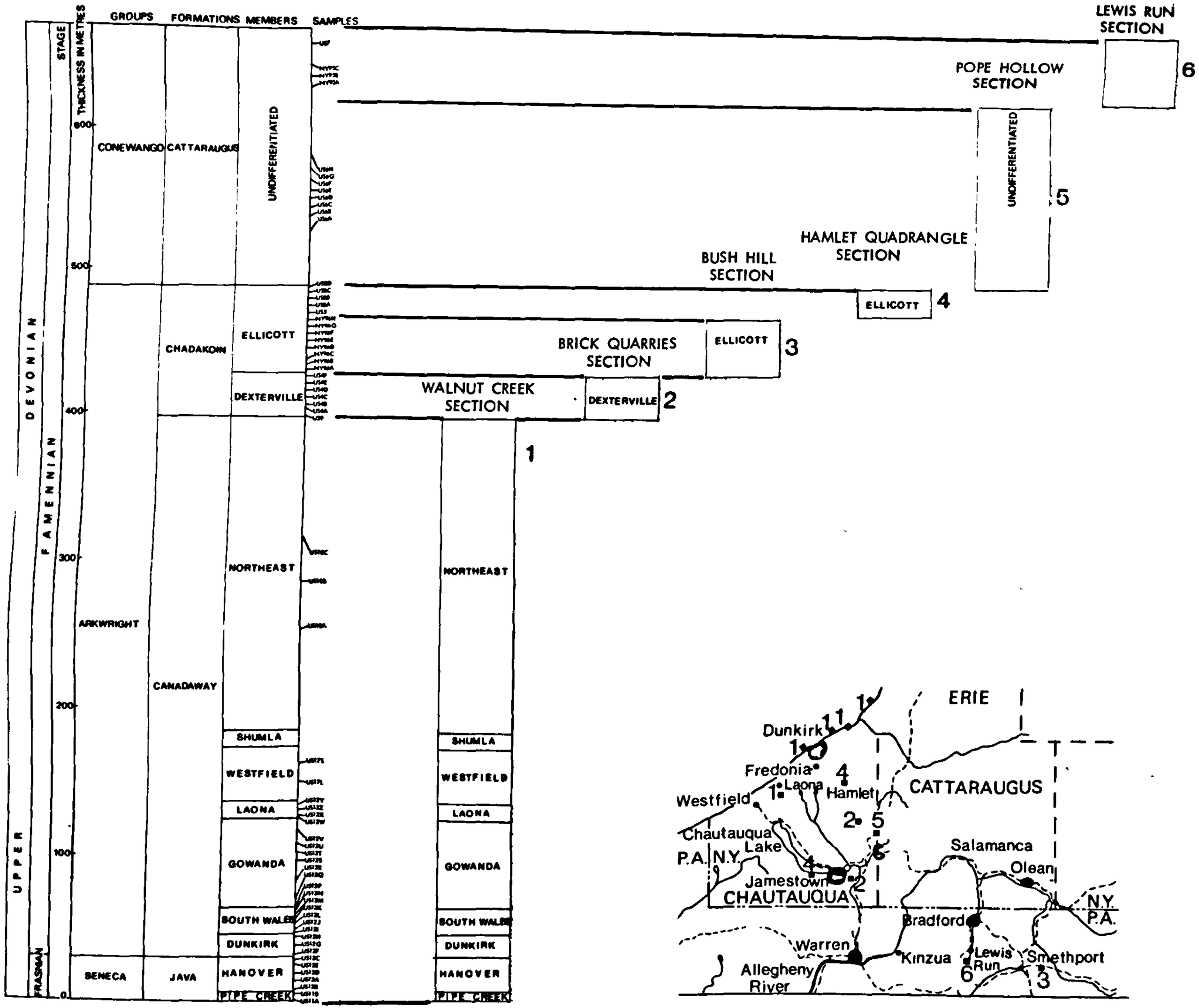
Text fig. 7.2. Variations in species number from eleven palynological samples.

The miospore assemblages of the lower Ellicott Member (The Bush Hill Section, siltstones) are much richer in species than those obtained from other parts of the sequence. Sandy siltstone sample (NY96B) shows flattening at 139 specimens, but the grey siltstone (NY96C) species flattening did not reach the "break off point" until 261 specimens had been counted.

Another sample from the Dexterville Member (US4F, grey-green siltstone) from New York State also shows a strong flattening when 222 specimens had been counted and no more species were encountered in the next 100 specimens.

The assemblages from shales of the middle Ellicott Member (NY96H and US5) have fewer species with relatively greater number of individuals of each.

The miospore assemblages from a sandstone sample (US7) and sandy shale (US6C) of the Cattaraugus Formation are the examples of fossil assemblages with only a few species.



TEXT FIG. 7.3. THE GEOGRAPHICAL LOCATIONS OF THE SECTIONS INVESTIGATED.

Numbers near each section correspond to the numbers on the location map.

COMPARATIVE PALYNOLOGY WITHIN THE AREAS STUDIED.

Ir this part of the chapter, comparison within the studied areas has been made. Four marine sections namely the Brick Quarries, Hamlet Quadrangle, Pope Hollow, and Lewis Run are compared palynologically with well dated, non-marine the Bush Hill Section. The stratigraphical horizons and geographical locations of all the six sections together with their samples investigated are shown in text fig. 7.3. Table 7.2. presents the ranges of miospores observed in marine strata.

COMPARATIVE PALYNOLOGY OF THE BUSH HILL (ELLICOTT MEMBER) AND BRICK QUARRIES (DEXTERVILLE MEMBER) SECTIONS.

The stratigraphical ranges and the levels of occurrence of all the miospores analysed from the Brick Quarries (Dexterville Member) and the Bush Hill (Ellicott Member) Sections are shown in table 7.3.

The miospore assemblages recorded from the Brick Quarries have been assigned to the Synorisporites flexuosus - Auroraspora varia (FV) Zone, while those recorded from the Bush Hill have been attributed to the Vallatisporites vallatus var. hystricosus - Retispora lepidophyta (HL) Zone because of the first appearance of the index fossils.

The material from the Brick Quarries Section yielded 45 species of miospores. Of the 78 species recorded from the two sections, only 32 are common to both assemblages. Forty-one per cent. species are regarded as common to both the Bush Hill and the Brick Quarries assemblages (see tables 7.7. and 7.8.)

| MIOSPORE ZONES | ? | STREELISPORA CATINATA-ANCYROSPORA NEOGRANDISPINOSA | | | | | | | | | SYNORISPORITES FLEXUOSUS-AURORASPORA VARIA | VALLATISPORITES VALLATUS VAR. HYSTRICOSUS - RETISPORA LEPIDOPHYTA | | | | | | | | |

By comparison with material from the Bush Hill, assemblages from the Brick Quarries are carbonized and the state of preservation is also poor. However, miospores which were quantitatively determined accounts for between 30 and 82 per cent., acritarchs range 5 and 52 per cent. and indeterminate elements I2 and 22 per cent. of the miospore/ microplankton assemblages.

In the Brick Quarries assembalge Vallatisporites vallatus var. hystricosus and Retispora lepidophyta have not been observed. The presence of these index fossils in the Bush Hill assemblage (in non-marine sequence) and in material from the Hamlet Quadrangle (in marine sequence) is a widespread biological event. Consequently, the base of the Bush Hill and Hamlet Quadrangle Sections is of Famennian age or Fa2c/Fa2d boundary within the Upper Famennian (in Belgian terminology) (see p. 243).

The Bush Hill assemblage contains, in addition, a number of distinctive forms that were not encountered in material from the Brick Quarries. These forms may prove to be of potential value as stratigraphical indicator: Pulvinispora quasilabrata, Convolutispora definita sp. nov., Knoxisporites literatus, Synorisporites richardsonii sp. nov., Auroraspora prostata sp. nov., A. prostata var. prostata var. nov., A. prostata var. elongata var. nov., A. versabilis and Retispora lepidophyta var. granda.

The Brick Quarries microflora contains four miospore forms which do not extend upward in the sequence: Samarisporites inusitatus, Auroraspora pseudocrista sp. nov. Rhabdosporites langi and

MIOSPORE SPECIES	BRICK QUARRIES SECTION DEXTERVILLE MEMBER							BUSH HILL SECTION ELLICOTT MEMBER							
	US9	US4A	US4B	US4C	US4D	US4E	US4F	NY96A	NY96B	NY96C	NY96D	NY96E	NY96F	NY96G	NY96H
Acanthotriletes horridus var. minutus	o	o													
Ancyrospora acadensis	o	o	o	o	o	o									
Auroraspora pseudocrista	o	o	o	o	o	o	o								
Ancyrospora neograndispinosa	o	o	o	o		o	o								
Samarisporites kedoae	o	o	o		o	o	o								
Aneurospora incohata	o	o	o	o			o	o	o			o			
Auroraspora torquata	o	o					o			o		o			
Auroraspora pallida	o	o	o	o	o		o	o		o		o	o	o	
Auroraspora submirabilis	o	o	o			o	o				o		o	o	
Auroraspora solisorta	o	o	o	o	o	o		o	o	o	o	o		o	
Auroraspora varia	o		o	o	o	o	o	o	o	o	o	o	o	o	o
Synorisporites flexuosus	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Apiculiretusispora plicata	o	o				o	o	o		o	o	o		o	o
Ancyrospora multifurcata	o	o	o	o	o	o	o			o		o		o	o
Streelispora catinata	o	o	o		o	o		o	o	o	o	o	o	o	o
Retusotriletes concretus	o	o			o	o	o	o			o			o	o
Samarisporites inusitatus		o													
Dictyotriletes sp.		o													
Ancyrospora ancyrea var. ancyrea		o		o	o										
Rhabdosporites langi		o			o										
Grandispora macroseta		o			o										
Grandispora echinata		o	o	o	o	o		o							
Grandispora echinula		o	o			o	o				o				
Calamospora nigrata		o		o	o		o	o	o			o	o		
Hystricosporites sp. aff. porrectus		o												o	
Punctatisporites glaber		o	o	o		o	o	o	o	o	o	o	o	o	o
Punctatisporites platirugosus		o							o	o	o				o
Auroraspora micromanifesta			o												
Aneurospora greggsii var. minuta			o			o	o	o	o	o	o	o	o	o	o
Streelispora distincta			o					o	o	o	o		o	o	o
Retusotriletes caperatus				o		o	o								
Retusotriletes sp.				o	o					o					
Apiculiretusispora fructicosa				o	o	o	o	o		o	o	o			
Calyptosporites perclarus				o	o	o	o	o	o	o	o	o	o	o	
Aneurospora greggsii				o	o	o	o	o	o	o	o	o	o	o	o
Punctatisporites minutus				o	o	o	o	o	o		o	o	o	o	o
Rhabdosporites parvulus					o			o	o	o					
Ambitisporites cf. avitus	o			o		o									
Auroraspora commutata	o		o		o	o	o	o	o	o	o	o	o	o	
Grandispora corunata			o												
Auroraspora callosa			o				o								
Acanthotriletes sp.			o										o		
Spelaeotriletes densatus			o		o	o	o	o	o		o				
Pulvinispora depressa			o	o	o	o	o	o	o	o	o				
Auroraspora poljessica			o	o	o	o	o	o	o	o	o	o	o	o	
Raistrickia clavata				o	o										
Auroraspora papillara				o	o										
Auroraspora cf. papillara				o	o										
Retusotriletes cf. concinnus				o	o	o									
Pulvinispora quasilabrata				o	o	o	o								
Calamospora pedata				o			o								
Calamospora liquida				o	o	o		o							o
Biharisporites parviornatus				o	o	o	o	o	o	o	o	o	o		
Auroraspora prostata				o	o	o	o	o	o	o	o	o	o		
Auroraspora prostata var. prostata				o			o	o							o
A. prostata var. elongata				o			o			o					
Synorisporites variegatus				o	o	o	o	o	o	o	o	o	o		
Knoxisporites literatus				o	o		o								
K. pristinus				o	o	o		o	o	o	o	o	o		
Convolutispora definita				o	o	o	o	o	o	o	o	o	o		
Verrucosisporites maculosus				o	o	o									
Convolutispora mellita				o	o	o	o	o	o	o	o	o	o		
Vallatisporites vallatus var. hystricosus				o	o	o	o	o	o	o	o	o	o		
Synorisporites richardsonii					o										
Raistrickia baculosa					o	o		o							
Punctatisporites stabilis					o			o	o						
Retispora lepidophyta					o	o		o		o					
R. lepidophyta var. granda					o					o					
Lophozonotriletes curvatus					o	o				o	o				
Verrucosisporites microtuberosus					o					o	o				
Auroradpora versabilis						o	o	o		o	o				
Raistrickia ampullaceae						o	o	o			o				
Auroraspora varia var. multifaria						o		o	o	o	o				
Emphanisporites rotatus						o									
Leiotriletes ornatus								o	o		o				
Dibolisporites sp.									o	o					
Hystricosporites porcatus										o					
Hystricosporites mitratus										o	o				

Direction of younging →

Table 7.3. Stratigraphical ranges of all the miospores recorded from the Brick Quarries and Bush Hill Sections.

Ancyrospora ancyrea var. ancyrea.

The species Auroraspora torquata and Ancyrospora multifurcata are well preserved in material from the Bush Hill, whereas these species were found to be poorly preserved in the marine sequence.

Retusotriletes caperatus sp. nov., Ancyrospora neograndispinosa sp. nov., and A. acadensis sp. nov. are commonly present in Dexterville sample but have not been encountered in material from the Bush Hill Section.

The sporadic occurrence of a distinctive species, Samarisporites kedoae in samples from the Brick Quarries and Hamlet Quadrangle may, however, be due to recycling.

In conclusion, the palynological evidence suggests that the strata of the Brick Quarries Section (Dexterville member) are older than those at the Bush Hill Section (Ellicott member). However, Tschudy (1969, p. 112) concludes that "dissimilarity of assemblages is not always indicative of differing ages; ..." because different origins or occupied different ecological habitats play an important role for the deposition of plant-microfossil assemblages.

COMPARATIVE PLAYNOLOGY OF THE BUSH HILL AND HAMLET QUADRANGLE (ELLICOTT MEMBER) SECTIONS.

The stratigraphical distribution of the 77 species and forms of miospores recorded from these two sections is summarised in Table 7.4.

The miospore assemblages obtained from the Bush Hill and Hamlet Quadrangle (Ellicott member) Sections have been assigned to the Vallatisporites vallatus var. hystricosus - Retispora lepidophyta (HL) Zone because of the continuous occurrence of the index fossils.

BUSH HILL SECTION | HAMLET QUADRANGLE SECTION

ELLICOTT MEMBER

MIOSPORE SPECIES	NY96A	NY96B	NY96C	NY96D	NY96E	NY96F	NY96G	NY96H	US5	US88A	US88B	US88C	US88D
Raistrickia clavata	o	o											
Auroraspora papillara	o	o											
Auroraspora cf. papillara	o	o											
Retusotriletes cf. concinnus	o	o	o										
Pulvinispora quasilabrata	o	o	o	o									
Calamospora liquida	o	o	o		o		o						
Biharisporites parviornatus	o	o	o	o	o	o	o	o					
Auroraspora prostata	o	o	o	o	o	o	o	o					
A. prostata var. prostata	o		o	o			o						
A. prostata var. elongata	o			o		o	o						
Knoxisporites literatus	o	o		o		o		o					
Verrucosisporites maculosus	o	o	o				o	o					
Convolutispora definita	o	o	o	o	o	o	o	o					
C. mellita	o	o	o	o	o	o	o	o					
Apiculiretusispora fructicosa	o		o	o	o		o		o				
Calyptosporites perclarus	o	o	o	o	o	o	o		o				
Knoxisporites pristinus	o	o	o		o	o	o	o	o				
Auroraspora varia	o	o	o	o	o	o	o	o	o	o			
Auroraspora poljessica	o	o	o	o	o	o	o	o	o	o			
Aneurospora greggsii var. minuta	o	o	o	o	o	o	o	o	o	o	o		
Vallatisporites vallatus var. hystricosus	o	o	o	o	o	o	o			o	o		
Pulvinispora depressa	o	o	o	o	o	o	o		o	o	o	o	
Aneurospora incohata	o	o		o			o	o		o		o	
Grandispora echinata	o						o	o	o	o			
Ambitisporites cf. avitus	o		o					o		o			
Streelispora distincta	o	o	o	o		o		o				o	
Auroraspora solisorta	o	o	o	o	o		o		o	o	o		o
Synorisporites flexuosus	o	o	o	o	o	o	o	o	o		o	o	o
Calamospora pedata	o			o								o	o
Retusotriletes concretus	o			o								o	o
Synorisporites variegatus	o	o	o	o	o	o	o	o		o		o	
Calamospora nigrata	o	o		o	o			o	o	o		o	
Auroraspora pallida	o		o		o	o	o		o	o	o	o	o
Streelispora catinata	o	o	o	o	o	o	o	o	o			o	
Punctatisporites minutus	o	o		o	o	o	o	o	o	o		o	
Punctatisporites glaber	o	o	o	o	o	o	o	o	o	o	o	o	o
Aneurospora greggsii	o	o	o	o	o	o	o					o	
Apiculiretusispora plicata	o		o	o	o		o	o	o			o	o
Raistrickia baculosa	o	o		o									
Punctatisporites stabilis	o		o	o									
Retispora lepidophyta var. granda	o				o								
Auroraspora commutata	o	o	o	o	o	o	o						
Lophozonotriletes curvatus	o	o			o	o							
Synorisporites richardsoni	o					o							
Retispora lepidophyta	o	o		o		o		o					
Spelaeotriletes densatus	o	o	o	o		o			o				
Punctatisporites platirugosus	o	o	o				o			o	o	o	
Verrucosisporites microtuberosus	o				o	o							o
Rhabdosporites parvulus		o											
Emphanisporites rotatus		o											
Auroraspora versabilis		o	o	o		o	o						
Auroraspora varia var. multifaria		o		o	o	o	o						
Retusotriletes sp.		o					o	o					
Raistrickia ampullaceae		o	o	o			o		o				
Ancyrospora multifurcata		o		o		o	o	o	o	o	o		
Auroraspora torquata		o		o			o	o	o	o	o		
Grandispora echinula			o						o				
Auroraspora callosa			o						o			o	
Auroraspora submirabilis			o		o	o	o	o	o	o	o		
Leiotriletes ornatus				o	o		o		o				
Dibolisporites sp.				o	o								
Acanthotriletes sp.				o							o		
Hystricosporites porcatus					o								
Hystricosporites mitratus					o	o							
Hystricosporites sp. aff. porrectus					o			o	o				
Grandispora macroseta							o						
Spelaeotriletes microverrucosus							o						
Retusotriletes goensis							o	o		o			
Retusotriletes caperatus							o	o	o				
Samarisporites kedoae							o	o	o		o		
Ancyrospora neograndispinosa								o		o	o		
Samarisporites sp. cf. S. kedoae									o				
Auroraspora sp.									o				
Geminospora lemurata											o		
Dictyotriletes cf. trivialis											o		
Acanthotriletes horridus var. minutus											o		
Ancyrospora acadensis											o		

Direction of younging →

Table 7.4. Stratigraphical ranges of all the miospores recorded from the Bush Hill and Hamlet Quadrangle Sections.

From Table 7.4., 7.7. it is evident that 41 species are observed as common to both the Bush Hill and Hamlet Quadrangle assemblages. However, two of these, Auroraspora varia and A. submirabilis appear to be almost mutually exclusive - the former being much more characteristic of the Bush Hill assemblage, and the latter of the Hamlet Quadrangle.

Auroraspora prostata and its varieties which were quantitatively determined accounts for up to 20% of the total assemblage. These forms were not encountered in material from the Hamlet Quadrangle. The species which are confined to the Hamlet Quadrangle assemblage include Spelaeotriletes microverrucosus (Kaiser) comb. nov., Samarisporites sp. cf. S. kedoae, Dictyotriletes cf. trivialis and Auroraspora sp.

In comparison with the Bush Hill assemblage, the Hamlet Quadrangle microflora is notably less diverse. Moreover, its constituent miospores are generally less well preserved, a circumstance which is perhaps the result of different depositional environments. In the Hamlet Quadrangle assemblage average percentage of Vallatisporites vallatus var. hystricosus present is only 2%, whereas well preserved specimens of Retispora lepidophyta were encountered only from one sample.

As has been mentioned above, of the 77 miospore forms from two sections, only 41 are common to both assemblages. A total of fifty-three species is apparently confined to the Hamlet Quadrangle assemblage. Fifty-three percent species are regarded as common to both the Bush Hill and Hamlet Quadrangle assemblages (see Table 7.8.)

In material from the Hamlet Quadrangle, the miospores at certain horizons constitute up to 80% of miospore/marine microplankton assemblages indicating for some of the samples a near shore environment. However, at specific level indeterminate elements

comprised up to 21% in some of the samples. Acritarchs have frequently been encountered throughout the section and comprise up to 48% of the total assemblage.

It might be argued that as the Hamlet Quadrangle Section is marine and the Bush Hill Section is non-marine, palynofacies differences might affect the range of the spores so as to invalidate direct correlation. Admittedly more work needs to be done to determine the extent of relationship between environmental factors and spore assemblages in the Devonian. However, those studies that have been done suggest that the representation of species in isochronous assemblages from different lithofacies tends to vary quantitatively rather than qualitatively, i.e., that whereas relative abundances of the certain constituent species may vary, the assemblages commonly may be correlated on the presence of many of the same constituent species, and a smilar succession of groups of species (Richardson 1969, p. 202 ff., Kuyl et al. 1955). The assemblages from the Bush Hill and Hamlet Quadrangle Sections are remarkably similar qualitatively, although the rocks differ in lithology. It can be suggested that the spores in them were derived from a common vegetational source on the margin of the sedimentary basin and were contemporaneous.

In summary, the miospore assemblages obtained from the sediments of the Bush Hill and Hamlet Quadrangle Sections are assigned to the HL Zone. The palynological evidence suggests the upper Famennian Fa2d age for these sections (see p. 216).

COMPARATIVE PALYNOLOGY OF THE BUSH HILL AND POPE HOLLOW SECTIONS.

Distribution of all the miospore forms recognised in both of these sections together with the ranges of restricted species, which are and may prove to be of potential value as stratigraphical

indicators, are plotted in Table 7.5.

The miospore sequences from the two sections reflect overlap in that the assemblages yielded from the Bush Hill Section are clearly comparable with those recorded from Pope Hollow Section although the latter are younger in age. It is relevant to indicate here the extent of similarities and differences.

The miospore assemblages obtained from these sections have been assigned to Vallatisporites vallatus var. hystricosus - Retispora lepidophyta Assemblage Zone because of the continuous occurrence of the index fossils.

Eight samples from the Chadakoin Formation, together with same amount of material indicated in text fig. 1.2, as un-differentiated Cattaraugus Formation are approximately 70 kms. apart. Material from the Chadakoin Formation belongs to northern Pennsylvania exposed at approximately 3 kms. East of Smethport, Road cut on route 6 and the other, containing specifically more or less identical assemblage, is from New York state outcropped along boundary between Carroll and South Valley Townships, Jamestown Quadrangle (see appendix p.355). The area at Pennsylvania called Bush Hill Section while that of New York known as Pope Hollow Section.

Fifty-five species have been recorded from the Pope Hollow Section. The material from the Bush Hill Section yielded sixty-five species of spores. Of the 80 species recorded from two sections, only 40 are common to both assemblages. Fifty percent. species are regarded as common to both the Bush Hill and Pope Hollow Sections (see Table 7.8.). Following points could be forwarded for such an unequal balance in the species distribution. Firstly, most of the rest are confined to either sections. Secondly, some of the forms terminate stratigraphically within the

MIOSPORE SPECIES	BUSH HILL SECTION ELLICOTT MEMBER								POPE HOLLOW SECTION CATTARAUGUS Fm.							
	NY96A	NY96B	NY96C	NY96D	NY96E	NY96F	NY96G	NY96H	USSA	USSB	USSC	USSD	USSE	USSF	USSG	USSH
Raistrickia clavata	O	O														
Auroraspora papillara	O	O														
A.cf. papillara	O	O														
Retusotriletes cf. concinnus	O	O	O													
Pulvinispora quasilabrata	O	O	O	O												
Apiculiretusispora fructicosa	O	O	O	O	O											
Calamospora pedata	O				O											
Calamospora liquida	O	O	O		O			O								
Biharisporites parviornatus	O	O	O	O	O	O	O	O								
Auroraspora prostata	O	O	O	O	O	O	O	O								
A. prostata var. prostata	O			O	O			O								
A. prostata var. elongata	O				O		O	O								
Apiculiretusispora plicata	O		O	O	O		O	O								
Knoxisporites literatus	O	O		O		O		O	O			O				
Streelispora distincta	O	O	O	O		O		O				O				
Synorisporites variegatus	O	O	O	O	O	O	O	O	O	O	O	O				
Knoxisporites pristinus	O	O	O		O	O	O	O					O			
Auroraspora varia	O	O	O	O	O	O	O	O		O			O			
Convolutispora definita	O	O	O	O	O	O	O	O	O			O		O		
Verrucosisporites maculosus	O	O	O				O	O		O				O		
Streelispora cotinata	O	O	O	O	O	O	O	O			O	O		O		
Grandispora echinata	O								O	O	O	O		O		
Aneurospora greggsii	O	O	O	O	O	O	O	O			O	O	O	O	O	
Punctatisporites minutus	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Punctatisporites glaber	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Aneurospora incohata	O	O			O								O	O	O	O
Ambitisporites cf. avitus	O		O		O	O	O								O	O
Auroraspora pallida	O		O		O	O	O								O	O
Retusotriletes concretus	O			O			O	O			O			O		O
Calamospora nigrata	O	O			O	O				O			O	O		O
Auroraspora poljessica	O	O	O	O	O	O	O	O					O		O	O
Pulvinispora depressa	O	O	O	O	O	O	O		O	O	O	O	O			O
Calyptosporites perclarus	O	O	O	O	O	O	O				O	O	O	O		O
Auroraspora solisorta	O	O	O	O	O		O			O	O	O	O	O	O	O
Aneurospora greggsii var. minuta	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Synorisporites flexuosus	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Vallatisporites vallatus var. hystricosus	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Raistrickia baculosa		O	O		O											
Punctatisporites stabilis		O			O	O										
Lophozonotriletes curvatus		O	O			O	O									
Auroraspora commutata		O	O	O	O	O	O									
Retispora lepidophyta var. granda		O				O		O								
Verrucosisporites microtuberosus		O				O	O			O						
Punctatisporites platirugosus		O	O	O			O						O			
Synorisporites richardsoni		O										O	O			
Retispora lepidophyta		O	O		O		O		O		O		O			O
Retusotriletes sp.			O													
Auroraspora versabilis			O	O	O		O	O	O							
Raistrickia ampulliaceae			O	O	O			O	O							
Emphanisporites rotatus			O									O	O			
Auroraspora torquata			O		O						O	O		O		
A. varia var. multifaria			O		O	O	O	O						O	O	
Ancyraspora multifurcata			O									O	O		O	
Rhabdosporites parvulus			O						O		O	O	O	O	O	O
Auroraspora callosa				O												
Grandispora echinula				O					O	O	O	O		O		
Auroraspora submirabilis				O			O	O	O	O	O			O	O	O
Leiotriletes ornatus					O	O		O								
Acanthotriletes sp.						O										
Dibolisporites sp.						O	O									
Hystricosporites sp. aff. porrectus							O									
H. porcatus							O									
H. mitratus							O	O								
Dictyotriletes sp.					O				O	O						
Ancyrospora neograndispinosa					O	O	O			O	O					
Spinozonotriletes sp.					O					O						
Vallatisporites vallatus var. major						O										
Grandispora corunata						O	O			O						
Retusotriletes goensis						O	O			O						
Ancyrospora acadensis						O	O	O		O						
Acanthotriletes horridus var. minutus							O			O	O					O
Retusotriletes caperatus							O	O		O	O					O
Grandispora macroseta								O		O	O					
Convolutispora vermiformis																
Auroraspora multirugata																
A. commutata var. major																
Emphanisporites cf. annulatus																
Spore type																
Grandispora sp. cf. G. spinosa																
Auroraspora micromanifesta																

Direction of younging →

Table 7.5. *Stratigraphical ranges of all the miospores recorded from the Bush Hill and Pope Hollow Sections.*

Bush Hill Section, while others are indeterminate at specific level. These factors are apparently contrclled by state of preservation of plant microfossils influenced by depositional environments which are entirely different in both of these areas.

The prolific and highly varied assemblages of the Bush Hill Section is marked by abudnant representatives of species Aneurospora greggsii and Auroraspora varia var. multifaria var. nov. which were quantitatively determined accounts for up to 43.5% and 39% respectively. Both of these elements are either absent or less than one percent as encountered in case of samples from the Pope Hollow Section. This factor could be environmentally controlled (see Tschudy 1969 p. 105).

In the Bush Hill Section average percentage of Vallatisporites vallatus var. hystricosus present is only 7% where-as Retispora lepidophyta was rarely encountered in the counts of 500 specimens. This section yielded abundant and in many cases well preserved miospores. The microfossils that could not be identified due to various reasons i.e. squashed, collapsed or ruptured nature of exine or partly covered with organic tissue, range 4-10% of the total assemblages. Other commonly dominant constituents include Auroraspora prostata sp. nov., A. prostata var. elongata var. nov., A. prostata var. prostata var. nov., Apiculiretusispora plicata, Aneurospora greggsii var. minuta var. nov., Synorisporites flexuosus (Jush) comb. nov., S. variegatus sp. nov., Knoxisporites literatus, K. pristinus, Punctatisporites glaber, Aneurospora incohata, Rhabdosporites parvulus, Biharisporites parviornatus and Streelispora catinata (Higgs) comb. nov.

No acritarchs have been observed in this section showing a strong evidence of non-marine influence and deposition was entirely in continental regime.

By comparison with the material from Bush Hill, assemblages from the Pope Hollow Section are impoverished and the state of preservation is also poor. Most of the microfossils, are highly carbonized and identification is frequently only possible at suprageneric level. The miospores at certain horizons constitute up to 90% of the miospore/marine microplankton assemblage (text fig. 7.1) indicating for some of the samples a near shore environment. However, at specific level indeterminate elements comprised up to 30% in some of the samples. Acritarchs have frequently been encountered throughout the section and comprise up to 24% of the total assemblage; 10% being sphaeromorphitae, 8% acanthomorphitae and 6% polygonimorphitae. Simple laevigate miospores are profusely represented whereas sculptured forms are rare.

This section contains, in addition, a number of distinctive forms that were not encountered in the material from the Bush Hill Section. The distinctive forms are as follows:

Retusotriletes caperatus sp. nov., R. goensis, Dictyotriletes sp., Convolutispora vermiformis, Emphanisporites cf. annulatus McGregor, Vallatisporites vallatus var. major comb. nov., Spinozonotriletes sp., Grandispora macroseta (Kedo) comb. nov., Auroraspora multirugata (Kedo) comb. nov., Ancyrospora neograndispinosa sp. nov. and A. acadensis sp. nov., Auroraspora commutata var. major, Grandispinosa sp. cf. G. spinosa, and Auroraspora micromanifesta.

Some other forms that are present in the Bush Hill Section but not observed in the Pope Hollow Section include Lophozonotriletes curvatus, Auroraspora prostata sp. nov. and its varieties, A. callosus (Kedo) comb. nov., A. papillara (Kedo) comb. nov., Hystricosporites mitratus, H. porcatus and H. sp. aff. H. porrectus.

MIOSPORE SPECIES	BUSH HILL SECTION ELLICOTT MEMBER								LEWIS RUN SECTION CATTARAUGUS FM.			
	NY96A	NY96B	NY96C	NY96D	NY96E	NY96F	NY96G	NY96H	NY95A	NY95B	NY95C	US7
Raistrickia clavata	O	O										
Auroraspora papillora	O	O										
A. cf. papillora	O	O										
Retusotriletes cf. concinnus	O	O	O									
Pulvinispora quasilabrata	O	O	O	O								
Calamospora pedata	O				O							
Apiculiretusispora fructicosa	O		O	O	O							
Calyptosporites perclarus	O	O	O	O	O	O	O					
Calamospora liquida	O	O	O		O			O				
Auroraspora prostata	O	O	O	O	O	O	O	O				
A. prostata var. prostata	O			O	O			O				
A. prostata var. elongata	O				O		O	O				
Knoxisporites literatus	O	O		O		O		O				
Knoxisporites pristinus	O	O	O		O	O	O	O				
Convolutispora definita	O	O	O	O	O	O	O	O				
Biharisporites parviornatus	O	O	O	O	O	O	O	O				
Streelispora distincta	O	O	O	O		O		O				
Leiotriletes ornatus	O		O	O	O		O	O				
Retusotriletes concretus	O			O			O	O	O			
Grandispora echinata	O								O			
Auroraspora varia	O	O	O	O	O	O	O	O	O			
Aneurospora greggsii	O	O	O	O	O	O	O	O	O	O		
Synorisporites variegatus	O	O	O	O	O	O	O	O		O		
Verrucosisporites maculosus	O	O	O				O	O			O	
Pulvinispora depressa	O	O	O	O	O	O	O				O	
Ambitisporites cf. avitus	O		O						O	O	O	
Aneurospora greggsii var. minuta	O	O	O	O	O	O	O	O	O	O	O	
Streelispora catinata	O	O	O	O	O	O	O	O	O	O	O	
Punctatisporites minutus	O	O	O	O	O	O	O	O	O	O	O	O
Punctatisporites glaber	O	O	O	O	O	O	O	O	O		O	O
Aneurospora incohata	O	O			O				O			O
Auroraspora pallida	O		O		O	O	O		O			O
Auroraspora solisorta	O	O	O	O	O		O					O
Synorisporites flexuosus	O	O	O	O	O	O	O	O	O		O	O
Calamospora nigrata	O	O			O	O						O
Auroraspora poljessica	O	O	O	O	O	O	O	O				O
Convolutispora mellita	O	O	O	O	O	O	O	O				O
Vallatisporites vallatus var. hystricosus	O	O	O	O	O	O	O	O	O	O	O	O
Punctatisporites stabilis		O			O	O						
Retispora lepidophyta var. granda		O					O					
Punctatisporites platirugosus		O	O	O				O				
Lophozonotriletes curvatus		O	O				O	O				
Auroraspora commutata		O	O	O	O	O	O	O				
Spelaeotriletes densatus		O	O	O	O		O		O	O		
Retispora lepidophyta		O	O		O		O				O	
Verrucosisporites microtuberosus		O					O	O			O	
Synorisporites richardsoni;		O									O	
Raistrickia baculosa		O	O		O						O	O
Retusotriletes sp.			O									
Auroraspora versabilis			O	O	O		O	O				
Raistrickia ampulliaceae			O	O	O			O				
Auroraspora varia var. multifaria			O		O	O	O	O				
A. torquata			O		O				O			
Rhabdosporites parvulus			O						O	O		O
Emphanisporites rotatus			O						O			O
Ancyrospora multifurcata			O		O		O	O	O			O
Auroraspora collosa				O								
A. submirabilis				O			O	O				
Grandispora echinula				O					O	O		
Leiotriletes ornatus					O	O		O				
Acanthotriletes sp.					O							
Dibolisporites sp.					O	O		O				
Hystricosporites sp. aff. porrectus						O						
H. mitratus						O	O					
H. porcatus						O						O
Ancyrospora acadensis									O			
Punctatisporites solidus									O			
Retusotriletes caperatus									O	O		
Convolutispora sp. aff. V. congestus											O	
Convolutispora vermiformis												O
Acanthotriletes horridus var. minutus									O			

Direction of younging →

Table 7.6. Stratigraphical ranges of all the miospores recorded from the Bush Hill and Lewis Run Sections.

In both areas the species V. vallatus var. hystricosus is consistently, and R. lepidophyta is less consistently present. Morphologically identical forms are encountered including R. lepidophyta and var. granda in both sections. Both of these forms have been observed having size range varying from 50-158μ m. The only difference recorded is the state of preservation. As has been discussed above Bush Hill Section yielded well preserved miospores while in case of Pope Hollow Section the preservation is rather corroded, and darker and in an inferior state of preservation when compared with material from the Bush Hill Section.

It can be concluded, keeping in mind the differences and points of similarities discussed, that discrepancies in stratigraphic ranges may be real in that these may reflect biochronological variations between the two geographically separated areas as well as lithologically distinct units; (Bush Hill Section of Chadakoin Formation belongs to Arkwright Group, Pope Hollow Section of Cattaraugus Formation belongs to Conewango Group). The paucity of certain species reflects the discontinuous distribution in its stratigraphical range.

On the other hand, since the two assemblages reflect two different environments, it would be rather reasonable to interpret that the absence of certain taxa including laevigate pseudosaccate miospores, some elements of megaspore dimension and a few species of anchor spined miospores in the Pope Hollow Section is because of distinct off shore depositional environment rather than a distinct temporal disparity.

COMPARATIVE PALYNOLOGY OF THE BUSH HILL AND LEWIS RUN SECTIONS.

Table 7.6. shows the distribution of miospores observed from material analysed from the Bush Hill (Ellicott member) and Lewis Run

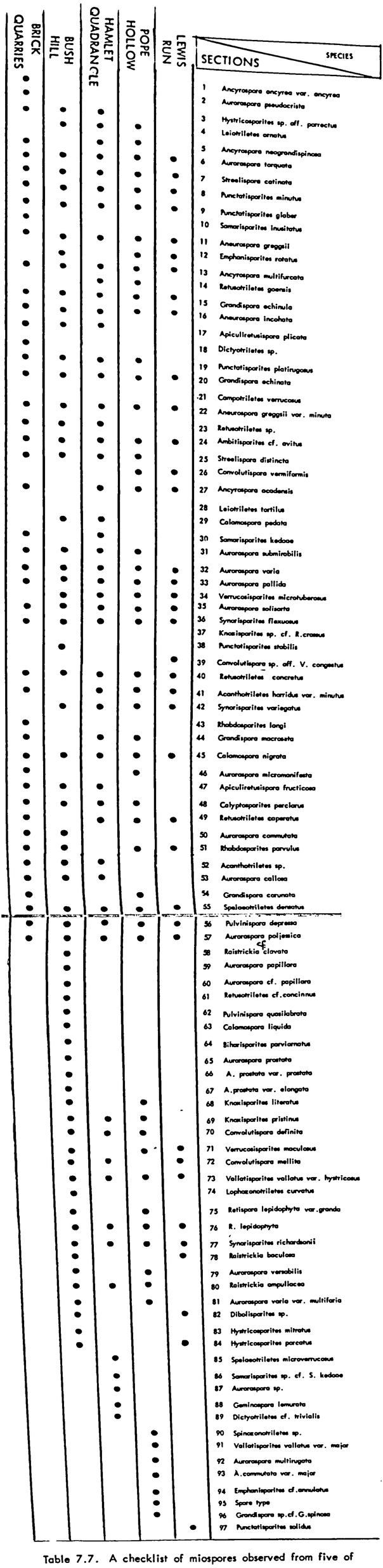


Table 7.7. A checklist of miospores observed from five of the sections during the present investigation.

(Cattaraugus Formation) Sections.

The mispore assemblages obtained from these sections have been assigned to Vallatisporites vallatus var. hystricosus - Retispora lepidophyta (HL) Assemblage Zone, because of the continuous occurrence of the index fossils.

A total of thirty-eight species is apparently confined to the Lewis Run assemblage (see Table 7.7.). Of the 71 species recorded from two sections, only 32 are common to both assemblages. Forty-five percent. species have been regarded as common to both the Bush Hill and Lewis Run assemblages (see table 7.8.).

By comparison with material from the Bush Hill, assemblages from the Lewis Run are rather corroded, darker and in an inferior state of preservation. Pyritized specimens are common. Most of the microfossils are highly carbonized. The miospores which were quantitatively determined accounts for between 54 and 78% of the miospore/marine microplankton assemblages. Indeterminate elements comprised up to 20% in one of the samples. Acritarchs have frequently been encountered throughout the section and comprise up to 30% of the total assemblage.

In Lewis Run assemblage average percentage of Vallatisporites vallatus var. hystricosus present is only 2% whereas Retispora lepidophyta was encountered only from one sample.

The Lewis Run assemblage contains, in addition, a few miospore forms that have not been encountered in material from the Bush Hill. Those are as follows:

Retusotriletes caperatus sp. nov., Punctatisporites solidus, Convolutispora sp. aff. Verrucosisporites - congestus, Convolutispora vermiformis, Ancyrospora acadensis.

The Lewis Run microflora yielded three species that have been reported from the Lower Carboniferous of Eastern Canada (Horton

SECTIONS	NUMBER OF SPECIES	TOTAL WITH BUSH HILL	COMMON WITH BUSH HILL	PERCENTAGE OF COMMON SPECIES WITH THE BUSH HILL
DEXTERVILLE (BRICK QUARRIES)	45	78	32	41 %
POPE HOLLOW	55	80	40	50 %
ELLICOTT (HAMLET QUADR-ANGLE)	53	77	41	53 %
LEWIS RUN	38	71	32	45 %
BUSH HILL	65	-	-	-

Table 7.8. Numerical comparison of species from the Bush Hill sequence with those from four of the sections investigated.

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Group). These are Punctatisporites solidus, Convotulisporites sp. aff., Verrucosisporites congestus and C. vermiformis. The last named has also been recorded from the Lower Carboniferous of Spitsbergen (Hughes & Playford 1961, Playford 1962). P. solidus and C. vermiformis are dominantly Carboniferous species but have been reported from the Upper Devonian. The presence of above mentioned species is not an indicative of Carboniferous age but of the early appearance of some Carboniferous forms.

CHAPTER 8

COMPARISON OF MIOSPORE ASSEMBLAGES

1. COMPARISON OF MIOSPORE ASSEMBLAGES WITH AREAS OUTSIDE NORTH AMERICA

BELGIUM

In 1974 Streel (in Becker et al.) established six 'florizones' of the Upper Frasnian to Lower Tournaisian (Fr-Tn1a) sediments of Belgium. With some reservations our palynological data (Upper Frasnian to Upper Famennian) seem to fit the Streel's assemblages. Some of the Belgian species are important quantitatively in the Belgian strata and are also well represented in New York State and Pennsylvania. For instance Aneurospora greggsii is well represented almost throughout the sequences in both the U.S.A. and Belgium. Miospores with multifurcate processes and laevigate spores with "banded" curvaturae e.g. Aneurospora incohata are present in the U.S.A. and Streel's assemblages. Synorisporites variegatus sp. nov. (under the name R. flexuosa) has been frequently recorded as almost being restricted to the Upper Famennian horizon in Belgium as well as in the area presently under investigation.

The miospore assemblages reported by Streel from the Matagne Barvaux beds, are similar to those described from the Java Formation of New York State. The following species are regarded to be coeval stratigraphically in both areas. Punctatisporites glaber, Aneurospora greggsii, Apiculiretusispora plicata ? Samarisporites inusitatus and miospores with multifurcate processes. This assemblage conforms with LT assemblage zone of Streel and indicates the Upper Frasnian Fr age (Table 8.I.).

The overlying Senzeilles - Montfort beds of Belgium yielded, in addition, Aneurospora incohata, A. greggsii var. minuta var. nov. (as Geminospora svalbardiae), Samarisporites kedoae (as S. sp. cf. H. acanthyrugosus), Auroraspora solisorta and Ancyrospora acadensis

sp. nov. (as A. langii). The presence of these species in the Canadaway Formation of New York State may indicate that the GP-GM1 zones of Streel correlate with the Canadaway Formation and indicate Fa1a-Fa2b ages. From the overlying Evieux beds of Belgium, Streel recorded Pulvinispora depressa, Retusotriletes caperatus (as R. sp.) Synorisporites variegatus (as R. flexuosa), and Grandispora corunata (as G. cf. uncata). This assemblage which has been described by the present author from the Dexterville member of New York State conforms with the VU zone of Streel indicating the upper Famennian Fa2c age.

The presence of the internationally recognized fossils Vallatisporites vallatus var. hystricosus and Retispora lepidophyta in the Chadakoin and Cattaraugus Formations of New York State and Pennsylvania, indicates that the latter are probably stratigraphically equivalent to the Comblain-Au-Pont beds of Belgium. This assemblage corresponds to the PL1 zone of Streel and indicates the Upper Famennian Fa2d age.

In short, of a total of 26 form genera recorded by Streel, 23 have been recorded during the present investigation. At the specific level, 70 miospore forms were observed from the Belgian Upper Devonian succession, of these 25 are present in the material investigated from New York State and Pennsylvania, U.S.A. Four species are regarded to be endemic to the Belgian Upper Devonian (see Table 8.3.). A striking dissimilarity in terms of miospore assemblages between these two areas is in the absence of distinctive large pseudosaccate forms such as Auroraspora torquata and Auroraspora pseudocrista sp. nov. in the Belgian strata. The former has been abundantly reported from south-east Ireland (see p.268 and table 9.I.).

NEW YORK STATE & PENNSYLVANIA PRESENT WORK			BELGIUM STREEL 1974			THE BRITISH ISLES	NORTH AMERICA		CANADA		NORTH AFRICA	POLAND	USSR		AUSTRALIA
Miospore Zones	Formation	Member	Stratigraphic units	Subdivision of stage	Spore 'florizone'	HIGGS 1975	WINSLOW 1962	PRESENT POSITION	SOUTH ONTARIO McGREGOR 1971	YUKON TERRITORY	MASSA ET AL 1976	TURNAU 1975	PRIPYAT DEPRESSION KEDO 1962	RUSSIAN PLATFORM NAUMOVA 1953	PLAYFORD 1976
HL	CATTARAUGUS	Undifferentiated	Comblain - Au - Pont	Fa2d	HL (PL)	Old Red Sandstone facies		Bedford Shale and Cleveland member of Ohio Shale	Bedford Shale		Tahara Formation Zone Eleven	Babilon 1 borehole	Dankov ? Lebedian	Dankov-Lebedian ?	Fairfield Formation
	CHADAKOIN	Ellicott							?						
FV		Dexterville	Evieux	Fa2c	VU						Aouinet Ouenine IV Zone Nine & Ten		Eletsk ?	Agramatch ?	?
		Northeast	Montfort	Fa2b	GM					Imperial Formation					
		Shumla				?	Ohio Shale	Ohio Shale							
				Fa2a					Kettle Point Formation						
		Westfield			GH										
				Fa1b											
CN	CANADAWAY	Laona										?	Zadonsk	Zadonsk	Napier Formation
		Gowanda													
		South Wales	Senzeilles	Fa1a	GP						Aouinet Ouenine III Zone Eight				
		Dunkirk													
		Hannover		Fr		?									
?	JAVA	Pipe creek	Matagne barvaux		LT										

Table 8.1. A correlation of the Upper Devonian sequences of New York State and Pennsylvania with those from other parts of the world, based on miospore assemblages.

THE BRITISH ISLES

Clayton et al. (1974) described miospore assemblages from the lower part of the Cork Beds of southern Ireland. Their assemblage of "type 1" is almost comparable with the HL zone described in the present study. In addition to index forms some stratigraphically important species are also present, not seen in Irish material described by Clayton et al. Those forms are as follows: Ancyrospora multifurcata (Winslow) comb. nov., Auroraspora pseudocrista sp. nov. Auroraspora torquata. Other accessory species are shown in Table 7.1. The miospore assemblage obtained from the Cattaraugus Formation compares with the assemblage described from Breamrock and Holeopen Members from Old Head of Kinsale section, Killowen and Carrigadda Member from South Ringabella section and Fennels Bay Member of North Ringabella section in southern Ireland.

Higgs (1975) gave an account of miospore assemblages from Hook Head, County Wexford, Upper Devonian and Lower Carboniferous transition beds of southeast Ireland. On the basis of selected records he recognized three palynological assemblages. Miospores described from sample K and J in his first assemblage cover approximately the HL zone as the material described in the present study (Table 8.I.). The taxa in common are shown in Tables 7.1. and 9.1.

On the basis of Retispora lepidophyta, Vallatisporites vallatus var. hystricosus, Aneurospora incohata, Streelispora catinata, Knoxisporites literatus, Synorisporites variegatus sp. nov., Auroraspora torquata, A. versabilis, A. commutata and A. poljessica our miospore assemblage assigned to the HL zone may probably lie somewhere approximately 80m. below the top of the Old Red Sandstone in Ireland. The upper sequence of the HL zone in the investigated area is also more or less similar to the HL (PL) zone assemblage

at Burrington Combe in the Mendip Hills, England and to the West Angle Bay, South Wales recorded by Dolby (1970). In these areas our HL zone can possibly be compared with assemblages from approximately 7 and 13m. below the base of the Lower Limestone Shales.

Utting and Neves (1970) also investigated the palynology of the Lower Limestone Shale Group (Basal Carboniferous Limestone Shale) and Portishead Beds (Upper Old Red Sandstone) of the Avon Gorge, Bristol, England. Their assemblage 3 recognized in sediments from the Portishead beds approximately 37.5m. below the Rhacophyton Beds compares closely with miospore assemblage HL described from New York State and Pennsylvania, U.S.A. The species in common include Ancyrospora multifurcata, Retispora lepidophyta , Synori, sporites flexuosus, Aneurospora incohata and Retusotriletes incohatus.

Among the lowest two zones (PL and NV) proposed by Neves et al. (1972) which were based mainly on the work of Neves and Dolby (1967), Dolby (1970), Dolby and Neves (1970) and Utting and Neves (1970) from the British Isles, our HL zone probably compares with their lowest PL assemblage zone.

British workers recorded altogether 43 miospore species from the Upper Devonian deposits; of these 26 have been recorded from New York State and Pennsylvania, U.S.A. Five species are considered to be endemic to the British Upper Devonian deposits (see Table 8.3.).

POLAND

Polish assemblages do not have any great points of similarity with the Upper Devonian miospores from the areas under consideration. However, Turnau's (1975) assemblage 4 reported from the norther Poland, is more or less comparable with the HL zone described in the present work. The Upper Devonian miospore assemblages from the U.S.A. and North Poland are characterized by the presence of

Retispora lepidophyta, Auroraspora versabilis, Aneurospora incohata, and Punctatisporites solidus.

The miospore species that occurred in the Polish Tournaisian sediments but have been observed from the Upper Devonian deposits during the present investigation are Punctatisporites glaber, P. stabilis, Aneurospora greggsii, Knoxisporites literatus, K. pristinus, Auroraspora micromanifesta and miospores with multifurcate spines.

A striking difference is in the absence of distinctive species Synorisporites flexuosus in Turnau's assemblages (also see chapter 9, p.264).

Of the eleven miospore forms reported from the Polish Upper Devonian deposits, only four have been regarded as common to both the U.S.A. and Polish assemblages. Only one species is considered to be endemic to the Polish Upper Devonian sediments (see Table 8.3.).

SOVIET UNION

Detailed comparative studies of miospore assemblages from various parts of the U.S.S.R. are hampered by the independent nomenclatural system used in the Soviet Union, the poor (inadequate) description of microfossils and the nature of their illustrations and the time taken for Russian publications to become available in western Europe, especially as translations.

Despite the above difficulties, a number of distinctive miospore species have been encountered from the area under consideration which can be compared with those documented in the Russian publications.

The first important and major work to be published was that of Naumova (1953). She described eight miospore assemblages from the Upper Frasnian and Famennian deposits of the Russian Platform

four corresponding to the Frasnian and the rest from the Famennian. In general there is little similarity between the composition of the Russian (Naumova's) assemblages and those recorded from the present material. It has been observed that a close similarity exists between miospores with pseudosaccate structural organization. Nevertheless, simple laevigate and cingulate forms also occur in both areas. The following species recorded by Naumova have been encountered from Chadakoin and Cattaraugus Formations during the present investigation. Lophozonotriletes curvatus, Auroraspora varia and Grandispora echinula. Two species described by Naumova Hymenozonotriletes rugosus and H. platyrugosus are thought to be comparable with Auroraspora varia var. multifaria var. nov.

Anchor spined miospores have been recorded in the Russian literature (reported from the Russian Platform and the Pripyat Depression), but none are regarded to be identical with the present forms. However, the nature of sculptural pattern developed on the miospores from both areas is worthy of special mention.

The next major work was that of Kedo (1957a,b, 1962, 1963), and Goloubtsov et al. (1968). Kedo and co-authors established fourteen miospore suites from the Pripyat Depression of Bielorussia S.S.R. The strata they investigated range in age from lower Famennian to Upper Tournaisian. Six miospore assemblages belonging to the Zadonsk, Elitsk, Lebedian, Dankov and Ozersk Khoransk Formations are in Famennian and the remaining eight are confined to three units belonging to the Tournaisian namely, Malevka, Cherepet and Kizel Formations. Following Naumova, Kedo established most of her miospore "complexes" on the relative abundance of certain species rather than on those forms with restricted vertical range.

In terms of miospore content the Russian stratigraphical units from the Zadonsk Formation to Upper Dankov Lebsdian Formation in the

Pripyat Depression are comparable with the Canadaway to Cattaraugus Formations exposed at New York State and Pennsylvania, U.S.A. (Table 8.I.).

Although all kinds of miospores have been observed in both areas, those possessing pseudosaccate structural organization are more common than the others. The following species are regarded as similar in both areas. Auroraspora varia, A. commutata, A. versabilis, A. polyjessica, Retispora lepidophyta, Grandispora echinula and Lophozonotriletes curvatus.

There are also some varied elements including smooth, cingulate and pseudosaccate miospores which have been encountered in the Famennian deposits during the present study that are confined to the Tournaisian strata in the Pripyat Depression. Those forms are: Calamospora nigrata, ?Dictyotriletes trivalis, Knoxisporites literatus, Vallatisporites vallatus var. hystricosus, V. vallatus var. major, Grandispora macroseta, Auroraspora pallida and A. submirabilis.

The absence of miospores with banded curvaturae such as Aneurospora greggsii and species with multifurcate appendages in the Russian deposits is a characteristic difference. Both of these forms have frequently been encountered during the present study and other parts of the northern hemisphere (see Table 9.I.).

It may be that some of the anomalies in the distribution of these elements may be more apparent than real.

NORTH AFRICA

Massa & Moreau-Benoit (1976) published an account of Devonian palynology from western Libya, Rhadames Basin. At the generic level a broad similarity exists between the miospore assemblages from Libya and that of U.S.A. Of the 33 forms genera recorded during the present investigation, 28 are common to both continents. Twenty-two miospore forms are considered to be identical to both

areas. Eleven species are regarded to be endemic to the Libyan Upper Devonian deposits (see Table 8.3). The miospore species that make their first appearance below the Frasnian in Libya but range sporadically up to the Famennian in both are; Retusotriletes goensis, Aneurospora greggsii var. minuta (as Geminospora svalbardiae), Apiculiretusispora plicata, Emphanisporites rotatus, E. cf. annulatus, Auroraspora micromanifesta, Rhabdosporites langi and R. parvulus.

In a broad sense palynological zone eleven investigated from the Tahara Formation is more or less comparable with the HL zone described in this work. Miospore zones nine and ten described from Aouinet Ouenine IV Formation are probably identical to the FV zone described herein (Table 8.1.). However, the absence of S. flexuosus in the Libyan zones nine and ten is a point of major difference. S. flexuosus makes its stratigraphical debut together with V. vallatus var. hystricosus and R. lepidophyta in the Libyan sediments. Miospores with mutifurcate processes have also been observed in Libyan deposits.

In summary, Massa & Moreau-Benoit's palynological zones 8-11, though differing slightly in accessory elements, can be compared with Java - Cattauraugus Formations investigated during the present study.

AUSTRALIA

Balme & Hassell (1962) published on the palynology of the Upper Devonian of Canning Basin, Western Australia. They made an attempt to correlate their material with Libyan latest Devonian sediments and with the Famennian assemblages from the Russian Platform described by Naumova (1953). The absence of apparent Retispora lepidophyta in the latter assemblage probably indicates strata older than the Australian material. Since no miospore

assemblages from Upper Devonian strata of other parts of northern hemisphere had been described at that time in the literature no comparison could be made by these authors.

On the whole Australian assemblages do not have any great points of similarity with the Upper Devonian miospores from New York State and Pennsylvania, U.S.A. However, twenty-two genera were recovered by Balme & Hassell and the miospores attributed to eleven genera are common to the two continents.

At the specific level apart from Retispora lepidophyta, Pulvinispora depressa and probably Hystricosporites sp. cff. H. porrectus, no other similar form was encountered in the material under consideration. Apart from Hystricosporites sp. aff. H. porrectus which is probably not identical to the Australian species, the association of the above forms suggests that Australian miospore assemblages are comparable with those assemblages confined between the top of the FV and almost top of the HL zone described in the present work (Table 8.1.). If one includes Hystricosporites sp. aff. H. porrectus within the morphographic circumscription of Balme & Hassell's species the range of the species in the Australian miospore assemblages covers almost the entire stratigraphic range of the miopsore species recorded from New York State and Pennsylvania, U.S.A.

By far the most comprehensive and up to date published palynological report on western Australian sediments is that of Playford (1976). In fact Playford enlarged on Balme & Hassell's (1962) observations by re-examining core samples no. 17 and 18 from borehole B.M.R.2, Laurel Downs, in the Fairfield Formation. The samples he investigated ranged from Upper Devonian to Lower Carboniferous and came from the marine (shallow water) sediments of the Fairfield Formation in the Canning Basin. The lithology comprised biogenic limestones and calcareous clastic sediments.

The Upper Devonian (Fa2d) microfloras, (Retispora lepidophyta assemblage described by Playford) bear only a superficial resemblance to the HL zone in New York State and Pennsylvania, U.S.A. investigated in the present work (Table 8.1.).

The species which are infrequently associated with index forms in both areas (U.S.A. and western Australian) include Pulvinispora depressa, Knoxisporites literatus, K. pristinus and Auroraspora micromanifesta.

It is of interest to note that Playford (loc. cit.) did not include in his systematics or in his range chart, simple, laevigate taxa such as Calamospora, Leiotriletes and Punctatisporites. This was because of their insignificant stratigraphical value and scarcity in his samples. The genus Retusotriletes is represented by only two new species which have not been encountered during the course of the present study. Comparison has therefore not been made with such smooth and/or laevigate groups of miospores.

The absence of Vallatisporites vallatus var. hystricosus in Balme & Hassell's (1962) report and only two more or less similar representatives, in Playford's assemblage may indicate that such miospore forms, if present, are not abundant in the Australian sediments.

The most obvious difference between the present material and the Australian sediments is in the absence of miospores with multifurcate processes and a distinctive species Synorisporites flexuosus in the miospore assemblages reported from western Australia (see p.21table 9.1.).

Balme & Hassell and Playford recorded altogether 53 miospore species from the Upper Devonian deposits; of these only 8 have been recorded from the material under investigation. Twenty-four species are regarded to be endemic to the Australian Upper Devonian (see table 8.3).

2. COMPARISON OF MIOSPORE ASSEMBLAGES WITH THOSE FROM OTHER PARTS OF NORTH AMERICA

THE U.S.A.

Winslow's (1962) paper is still one of the major contributions on North American Upper Devonian palynology ever published. In her comprehensive and valuable work she dealt with megaspores, miospores and microplankton. The strata she investigated range in age from Middle Devonian to the Mississippian transition measures and came from Ohio, U.S.A. A number of miospores described and illustrated are comparable with the Upper Devonian-Lower Carboniferous assemblages reported from elsewhere. Worthy of special mention is the absence of diagnostic macrofossils records in the succession, consequently the position of her sytematic boundary is known to be tentative. The part of succession investigated by Winslow is summarised below in Table 8.2.

ROCK UNITS	SYSTEM
Logan Formation Cuyahoga Formation Sunbury Shale Berea Sandstone Bedford Shale	Mississippian
Cleveland Member of Ohio Shale Ohio Shale	Upper Devonian
Olentangy Shale	Middle Devonian

Table 8.2. showing the sequences of Ohio, investigated by Winslow (1962)

Winslow (loc. cit.) placed Ohio Shale and Cleveland Member of Ohio Shale into the Upper Devonian and the overlying rock units the Mississippian.

AREAS	NUMBER OF SPECIES	COMMON WITH NEW YORK STATE AND PENNSYLVANIA	ENDEMIC	PALAEO-LATITUDE
POLAND	11	4	1	3°S
AUSTRALIA	53	8	24	10°S
THE BRITISH ISLES	43	26	5	12°S
BELGIUM	70	25	4	15°S
NEW YORK STATE AND PENNSYLVANIA	97	-	-	22°S
NORTH AFRICA	145	22	11	33°S

Table 8.3. A comparison in number of species from the Upper Devonian of New York State and Pennsylvania with those from other parts of the world.

The evidence of the spore assemblages accrued from Bedford Shale and Berea Sandstone is in agreement with an Upper Devonian age (Famennian). In general the miospores recorded from the Ohio Shale to Bedford Shale in above sequence in the Ohio, are in many respects similar to those described from the Java to Cattaraugus Formations of New York State and Pennsylvania, U.S.A. (Table 8.I.). The most striking similarity is in the existence of the taxon Ancyrospora multifurcata as Dicrospora multifurcata Winslow including both varieties multifurcata and impensa. These distinctive forms occurred from uppr part of the Olentangy Shale and persisted to top of the Bedford Shale in Winslow's sequence. In the area investigated these species are infrequent throughout the sequence. Another miospore which is common to both areas is Hystricosporites porcatus (Dicrospora porcata of Winslow). Allen (1965) recorded identical specimens from Givetian deposits in North and Central Vestspitsbergen. In the U.S.A. the taxon is vertically restricted to latest Devonian (Berea Sandstone), in the studied material the form is also found to be confined to the Uppermost Devonian.

Other species which are common and excellent stratigraphical markers are Vallatisporites vallatus var. hystricosus and Retispora lepidophyta. The geographical distribution of these index fossils is remarkably widespread and they are used as inter-regional correlation tools. In Ohio, Winslow recorded some miospore forms referred to as Cirratriradites hystricosus and Lycospora ? sp. A. which appear to be identical to Vallatisporites vallatus var. hystricosus. This form is restricted to the upper Cuyahoga Formation and to the mid Logan Formation. However the species shows its stratigraphical debut at the base of Bedford Shale, within the range of R. lepidophyta as in other parts of the world.

Winslow investigated a distinctive miospore species known

as Endosporites lacunosus which is usually accepted as equivalent to Retispora lepidophyta. It makes its debut high in the Cleveland Member of the Ohio Shale and occurs in abundance up to the top of Berea Sandstone. R. lepidophyta again appears at the base of the Cuyahoga Formation after dying out at the top of the Berea Sandstone. Its isolated occurrence in the Cuyahoga Formation (only two specimens) may weli indicate reworking since it is not present in the underlying Sunbury Shale. Winslow (loc. cit.) recorded abundantly 'Endosporites lacunosus' from the Cleveland Member of Ohio Shale at locality one but she also observed many specimens in the overlying Bedford Shale at localities 1,2, and 3 and in the Berea Sandstone at localities 5 and 9.

The large pseudosaccate miospore Endosporites chagrenensis Winslow has an almost identical structural organization to Auroraspora torquata Higgs. Also the size is comparable in both forms from the two areas. E. chagrenensis is restricted to upper part of the Ohio Shale in Winslow's succession and A. torquata is similarly restricted in the area under study.

Smooth laevigate forms such as Punctatisporites, cingulate elements e.g. Reticulatisporites (probably some form of the genus Knoxisporites), and the sculptured pseudosaccate genus Grandispora, have all been observed in both areas. Spores of megaspore dimension are also present in both localities.

Radforthia radiata Winslow which is regarded as synonymous with Emphanisporites rotatus occurs consistently in the Ohio Shale, Bedford Shale and sporadically in the Sunbury Shale and Logan Formation. Its presence in the latter formation may be due to re-working since the species is not found in the underlying Cuyahoga Formation. In the area investigated the form is spasmodically represented throughout the sequence.

It can be concluded that the miospore sequence described in this work is comparable to the section investigated by Winslow from the Ohio Shale to the Bedford Shale in Ohio, U.S.A.

CANADA

McGregor (1960) investigated the palynology of the Upper Devonian (Frasnian or probably Famennian) from Melville Island Canada Arctic Archipelago. He analysed bituminous coal samples which may represent a restricted microfloras. However, his miospore sequence is perhaps equivalent to the Java and part of the Canadaway Formation in New York State, U.S.A. On the whole the miospores described by McGregor are very different from those observed during the present study. Some similarities are offered by genera notably Biharisporites, Verrucosisporites, Convolutispora and smooth laevigate forms such as Punctatisporites and Leiotriletes.

McGregor (1970) recovered 'Hymenozonotriletes lepidophytus' Kedo and associated miospores from the Devonian of Canada. He examined three widely spaced localities at the horizon of the Devonian - Carboniferous boundary. It is unfortunte that the age of some of the sections investigated was not established on the basis of fauna. However, the miospore assemblages described by McGregor are similar to Vallatisporites vallatus var. hystricosus - Retispora lepidophyta (HL) zone as in the present study.

1. Southern Ontario:

Four formations namely Kettle Point, Bedford, Berea and Sunbury were analysed palynologically from two wells six kilometres apart and from surface material. To support the palynological results palaeonotological dating is available from conodonts (although not for the particular sections studied). It is of

interest that the Kettle point Formaticn (black shale) is the only stratigraphical unit of proved Devonian age and offers closest similarities with the Java, Canadaway and Chadakoin Formations investigated during the present work (Table 8..I.). Convolutispora sp. in McGregor & Owens (1966 pl. 28, fig. 19) appears to be similar to the present form referred to as Convolutispora mellita. Some of the specimens similar to Emphanisporites cf. E. rotatus in McGregor & Owens (loc. cit. pl. 28, fig. 4) have been observed during this study. Verrucosisporites congestus Playford in McGregor & Owens (loc. cit. pl. 28, fig. 15) is probably similar in construction to the form referred to as C. sp. aff. V. congestus in this work. ?Perotriletes sp. McGregor & Owens (loc. cit. pl. 28, fig. 25) is identical to present form of Synorisporites flexuosus (Jush) comb. nov., while the figures 17, 18 and 21 illustrated on the above mentioned plate appear similar to Synorisporites variegatus sp. nov. ?Hymenozonotriletes varius Naumova var. minor Naumova in McGregor & Owens (loc. cit. pl. 28, fig. 24) has also been recorded from the present material. The index forms are, of course, common having identical morphographic circumscription. An equally striking difference is in the absence of multifurcate-spined miospores in the Kettle Point Formation.

The Bedford Formation (silty and sandy shales) also contains some miospore elements common to the underlying Kettle Point Formation. The miospores which are common to the present material are Knoxisporites literatus, Aneurospora incohata, Ancyrospora multifurcata (Winslow) comb. nov. and Retusotriletes sp. in McGregor (1970, pl. 21, fig. 8) which is regarded to be identical to R. caperatus sp. nov. The overlying Berea Sandstone Formation is identical in miospore components to the underlying Bedford Formation. Berea Sandstone Formation is considered to be of Strunian age. Presence of Spathognathodus inornatus suggests an uppermost Famennian age for

Bedford Formation.

In the Sunbury Formation spores similar to Ancyrospora multifurcata are probably not present (neither illustrated nor listed by McGregor) but a form similar to Spelaeotriletes microverrucosus is illustrated as unidentified (pl. 22, fig. 15).

2. Maritime Provinces

The miospore assemblages have been recovered from the lower part of the Horton Group in Nova Scotia. No palaeonotological evidence is available to support the palynological results. However, the following common species have been encountered in both areas: Aneurospora incohata, Synorisporites flexuosus as Hymenozonotriletes famenensis in McGregor (1970 pl. 23, fig. 4), Ancyrospora multifurcata as ?Dicorspora multifurcata (only one spine illustrated) and index forms V. vallatus var. hystricosus - Retispora lepidophyta.

3. Yukon Territory

McGregor (1970) analysed two samples from near the top of the Imperial Formation from the Trial River, three kilometres east of the Richardson Mountain front, in Yukon Territory. Here again there is no palaeontological evidence as to age of the section. In addition the well known index species Knoxisporites literatus and Grandispora echinata may bear some resemblance to miospores recorded from New York State and Pennsylvania, U.S.A. On the basis of miospores recorded by McGregor the age of the section is considered to be Strunian.

McGregor (in McGregor & Uyeno 1972) established six spore assemblages of Siegnenian to lower Famennian from Melville and Bathurst Islands, in the Franklinian Miogeosyncline of the Canadian

Archipelago. These assemblages are on the whole very different from the Upper Devonian misopores from New York State and Pennsylvania, U.S.A. However, spores probably belonging to the genera Retusotriletes, Apiculiretusispora, Geminospora, Dibolisporites, Convolutispora, Emphanisporites, Samarisporites, Spinozonotriletes, Rhabdosporites, Grandispora, Calyptosporites, Auroraspora, Ancyrospora and Hystricosporites occur in both.

More recently Chi & Hills (1976) published a comprehensive paper which deals with megaspores and miospores from Arctic Canada. Seven assemblage zones of Givetian to Famennian age have been established on the basis of the relative abundance and the first or last occurrence of characteristic species. The majority of spores, however, are from the Givetian and Frasnian parts of the succession. The spore floras of Arctic Canada are very different from those from the New York State and Pennsylvania, U.S.A. However, Grandispora multiapicalis Chi & Hills which has been recorded from Frasnian deposits is similar in construction to Ancyrospora multifurcata (Winslow) comb. nov. It is interesting to note that Chi & Hills (loc. cit.) recorded Rhabdosporites langi (Eisenack) Richardson from the Givetian to Frasnian sediments, while during the present study it has been found from Famennian deposits. In Europe R. langi appears to be limited to the Eifelian-Frasnian deposits.

CHAPTER 9

GEOGRAPHICAL VARIATIONS IN THE MIOSPORE ASSEMBLAGES

GEOGRAPHICAL VARIATIONS IN THE UPPER DEVONIAN MIOSPORE ASSEMBLAGES

INTRODUCTION: In the proceedings of the 17th Inter-University Geological Congress held in Queen Mary College (University of London) 17-19 December, 1969, several contributors discussed the concept of 'province' and offered definitions (see Middlemiss et al. 1971). Charig (in Middlemiss et al. p. 111) considers that province is an entirely arbitrary concept. Holland (in Middlemiss et al. p. 61) quotes from Darlington's well known book on 'Zoogeography' (Darlington 1957): "The great difficulty with faunal region is not philosophical but practical". Funnell (in Middlemiss et al. p. 192) quotes Valentine's definition of a province as simply a collection of communities associated in space and time. In the author's opinion the floral province should be recognized on the basis of several different forms of spores including endemic elements and it should have rather precise boundaries.

Sullivan (1965) established three floral provinces in Viséan characterized by distinctive miospore associations. These are referred to as the Monilospora suite, the Grandispora suite, and the Kazakhstan suite. The Monilospora suite was established for the miospore assemblages described from western U.S.S.R., Spitsbergen and northern Canada. The miospore associations in western Europe and U.S.A. had been termed the Grandispora suite and third Kazakhstan suite in the Kazakhastan area of central U.S.S.R.

Sullivan (1967) also distinguished two miospore suites from data accrued from the Tournaisian sediments, the Vallatisporites suite and the Lophozonotriletes suite. The former occurred in southeast Canada, U.S.A., western Europe, Australia and probably

the Middle East. The miospore assemblages reported from Spitsbergen and western U.S.S.R. were called the Lophozonotriletes suite. Sullivan could not delimit the Tournaisian floral provinces geographically because of insufficient data from the strata of proved Tournaisian (Kinderhookian) age. He observed, however, that Vallatisporites and Lophozonotriletes suites occupy the same geographical position as the younger Grandispora and Monilospora suite respectively.

During the last few years attention has been concentrated on Devonian spores to differentiate them into provinces. It is difficult, as will be evident from Table 9.1. to differentiate the Upper Devonian microfloras on a global scale. This difficulty has also been noted by Rigby & Schopf (1969) who state that the Devonian microfloras seem to lack provinciality. Chaloner & Lacy (1973, pp. 273-274, text fig. 1) on macrofossils also reached a similar conclusion and postulated that it was only after the Late Carboniferous to Early Permian that distinctly geographically restricted segregation became evident. Bar & Riegel (1973) observed distinct phytogeographical segregations between Gondwanaland and Euramerica in the Middle Devonian, while the microfloras of the Upper Devonian and Lower Carboniferous were found rather uniform in composition. Recently Richardson & McGregor (1977 M.S.) made an attempt of differentiating Devonian microfloras into provinces. They achieved the same result as proposed by Bar & Riegel (loc. cit.). Richardson & McGregor (loc. cit.) found a remarkable floristic similarities in the Lower, some differentiation in the Middle Devonian assemblages but again little microfloristic variation in the Upper Devonian.

It is worth mentioning that apart from microfloras, faunas also provided negative evidence concerning the provincialism in

	MIOSPORE SPECIES	OCCURRENCE								
		U.S.A.	Canada	Ireland	England & Wales	Belgium	Poland	North Africa	USSR	Australia
Multifurcata suite	Miospores with multifurcate spines, Hystricosporites/Ancyrospora multifurcata.	■	■	■	■	■	●	■		
	Aneurospora greggsii	■	■	■		■	●	○		
	Aneurospora incohata	■	■	■	■	■	■	■		
	Synorisporites flexuosus	■	■	○	■	■		■	■	
	Auroraspora versabilis	■		○	■	■	■		■	
	Auroraspora commutata	■		■	■	○			■	
	Auroraspora poljessica	■		■	■	■			■	
	Auroraspora varia	■	■	○					■	
Ubiquitous species	Retispora lepidophyta	■	■	■	■	■	■	■	■	■
	Vallatisporites vallatus var. hystricosus	■	■	■	■	■	●	■	●	●
	Knoxisporites literatus	■	■	■	■	○	●	■	●	■
	Knoxisporites pristinus	■			●	■	●			■
	Auroraspora micromanifesta	■		■	■		●	■	○	■
	Hystricosporites porrectus	■								■
	Pulvinispora depressa	■				■				■
	Punctatisporites solidus	■	●				■			○
Frustulentus suite	Granulatisporites frustulentus									■
	Apiculatisporis morbosis									■
	Convolutispora fromensis									■
	Camptotriletes balmei									■
	Cirratriradites impensus									■
	Hymenozonotriletes scorpius									■
	Diaphanospora riciniata									■
	Grandispora notensis									■
	Leiozonotriletes laurelensis									■
Miospores common to U.S.A. and Ireland	Calamospora liquida	■		■						
	Retusotriletes concretus	■		■						
	Retusotriletes sp.	■		●						
	Apiculiretusispora fructicosa	■		■						
	Pulvinispora quasilabrata	■		■						
	Geminospora lemurata	■		■						■
	Emphanisporites ?rotatus	■		■			●	■		
	Convolutispora vermiformis	■		■						
	Streelispora catinata	■		■						
	Synorisporites variegatus	■		■						
	Grandispora corunata	■		■						
	Retispora lepidophyta var. granda	■		■						
	Auroraspora torquata	■		■						
	Hystricosporites porcatus	■		■						

■ Recorded from Upper Devonian ● Recorded from Lower Carboniferous O Dubious specific assignment.

Table 9.1. Regional comparison of selected Upper Devonian miospore species.

the Upper Devonian. House (in Middlemiss et al. p. 78) concludes "it happens that I am particularly interested in Devonian ammonoides and there is little evidence of separation into province in the Devonian for them". Pointing to the possibility of provincialism in the Lower Devonian, House (loc. cit. p. 77) states "Provincial distributions in the early Devonian tend to be lost by the late Devonian". In the Eastern North America, Oliver (1976) delineated distinct provincialism of rugose corals in the Early Devonian. He observed that percentage of endemic forms were decreased through the Middle Devonian to zero in the early Late Devonian. Bar & Riegel (1974) indicated that general tendency of the floristic evolution has been confirmed for macrofloras. In conclusion, it can be regarded that both faunas and floras show little evidence for provinciality in the Upper Devonian.

SALIENT FEATURES OF THE COMPOSITION OF THE UPPER DEVONIAN MIOSPORE ASSEMBLAGES

It is not considered appropriate to list here all those miospore forms recorded by various workers from the Upper Devonian sediments in the different parts of the globe. These elements have been discussed in detail in a separate chapter, 'Comparison of miospore assemblages', see pp.242-60 , however, the characteristic Upper Devonian forms are given below.

THE U.S.A: From United States Winslow (1962) recorded for the first time some distinctive miospores. These were Ancyrospora multifurcata, and a number of lacunate pseudosaccate forms some with reticulate ornament e.g. Retispora lepidophyta (Endosporites lacunosus of Winslow), and others which are smooth such as Endosporites chagrenensis which is probably a species of the genus Auroraspora. The latter form is identical in size to

Auroraspora torquata and has been recorded abundantly during the present investigation. Higgs (1975) also reported the presence of A. torquata from the Upper Devonian of Ireland (see Table 9.1.). Winslow further recorded, in the Ohio sequence, the cingulate form Vallatisporites vallatus var. hystricosus. However, Winslow did not record Synorisporites flexuosus which is surprising since the latter species is as important element in strata of equivalent age from New York State and Pennsylvania, U.S.A. The absence of S. flexuosus may be due to facies change; Winslow analysed material from open marine facies.

Warg & Traverse (1973) analysed some carbonaceous shales and coals from central Pennsylvania, U.S.A. All their samples contained spores but they observed that there were differences in the relative abundance in samples of different lithologies. Warg & Traverse (loc. cit.) recorded the presence of Retispora lepidophyta and other miospores which include Ancyrospora multifurcata and Synorisporites flexuosus. The minutely ornamented form equipped with banded curvaturae is illustrated as Cyclogranisporites sp. which is probably similar in construction to Aneurospora greggsii.

CANADA: McGregor (1970) and McGregor & Owens (1966) illustrated a miospore assemblage from faunally controlled Upper Devonian deposits namely the Kettle Point Formation (black shale) from southwestern Ontario. Some of the species they recorded have an equatorial crassitude with verrucate and murornate sculptural elements. For instance McGregor & Owens (1966, pl. 28, fig. 25) have illustrated a miospore referred to ?Perotriletes sp. which although undescribed appears to resemble Synorisporites flexuosus. In the systematic section this Canadian form is placed in synonymy with the latter. Another miospore species illustrated by the same authors (McGregor & Owens, pl. 28, figs. 17-18, 21) but unidentified by them is

probably identical to Synorisporites variegatus sp. nov. Further Auroraspora varia var. minor and an unidentified form similar to A. poljessica (pl. 29, fig. 11) are also present in the Canadian Upper Devonian sediments.

In addition to R. lepidophyta and V. vallatus var. hystricosus, McGregor (1970) also recorded from the Bedford Shale Formation Ancyrospora multifurcata and a smooth form with 'banded' curvaturae Aneurospora incohata. ?Retusotriletes punctatus in McGregor (1970, pl. 22, fig. 9) is probably similar in construction to Aneurospora greggsii. However, the latter is well documented from the Ghost River Formation of western Alberta, which is probably Upper Givetian to Lower Frasnian in age (McGregor 1964).

SOUTH AMERICA: Miospore assemblages from South America have not been described in detail, however, Daemon et al. (1971) recorded some miospores from Brazil including one identical to R. lepidophyta.

THE BRITISH ISLES: A number of authors including Neves & Dolby (1967), Dolby & Neves (1970), Dolby (1970), Utting & Neves (1970) and Allen in Gayer et al. (1973) have published papers containing the results of investigations from Upper Devonian sediments in the British Isles. Almost all of these workers have reported the presence of Ancyrospora multifurcata, Synorisporites flexuosus and Aneurospora incohata. Apart from Retispora lepidophyta and Vallatisporites vallatus var. hystricosus, Allen in Gayer et al. illustrated some specimens of Auroraspora from shale and micaceous siltstones (South Wales). The laevigate pseudosaccate forms present are Auroraspora versabilis and illustrations (Allen in Gayer et al. pl. 15, figs. B-C) which appear to be identical to the species A. commutata.

A more or less identical miospore assemblage has also been

recorded from the Upper Devonian of southeast Ireland (Higgs 1975). Higgs reported the presence of Ancyrospora multifurcata, a form referred to as Hymenozonotriletes famenensis (Higgs loc. cit. pl. 5, fig. 6) is identical to Synorisporites variegatus sp. nov. He also observed Aneurospora incohata and the miospore illustrated as Apiculiretusispora granulata Owens (in Higgs 1975, pl. 1, fig. 26) which is similar in construction to Aneurospora greggsii. In addition to R. lepidophyta and V. vallatus var. hystricosus, Higgs (loc. cit.) also observed large pseudosaccate forms such as Auroraspora torquata Higgs. Other similar forms are Auroraspora poljessica, A. commutata and A. micromanifesta. A miospore labelled Hymenozonotriletes versabilis appears to be identical to A. commutata. Also Apiculiretusispora fructicosa Higgs occurs in the Irish Upper Devonian sediments as well as in the present material (See Table 9.1.).

BELGIUM: Streel has published a number of papers representing the result of the Upper Devonian palynological investigations. Recently Streel (in Becker et al. 1974) presented a revised miospore range chart based on material from Belgium, Germany and France. He recorded miospores including smooth laevigate, cingulate, pseudosaccate forms and those with multifurcate appendages. His assemblages show close similarities to those described from equivalent strata in Britain and U.S.A. (present study). The most obvious similarity between the present assemblages and those of Belgian is in the abundance of sculptured miospore forms equipped with 'banded' curvaturae e.g. Aneurospora greggsii. Other characteristic forms from Upper Devonian assemblages are R. lepidophyta, V. vallatus var. hystricosus, Synorisporites flexuosus, A. incohata and miospores with multifurcate appendages. Laevigate pseudosaccate forms are also equally represented in the Belgian Upper Devonian succession. These are Auroraspora versabilis and A. solisorta. Specimens

referred to by Streel as A. poljessica (pl. 20, figs. 8-9, 12) are probably identical in organization to Calyptosporites perclarus sp. nov. Smarisporites cf. Hymenozonotriletes acanthyrugosus Chibricova appears to be identical to Samarisporites kedoae (Riegel) comb. nov. It is of interest to note that a specimen referred to by Streel as Ancyrospora langii is similar to Ancyrospora acadensis sp. nov.

POLAND: Little is known of the stratigraphical distribution of miospores in the Upper Devonian of Poland. Only one work, that of Turnau (1975) which deals with the Famennian and Tournaisian microfloras from boreholes of northern Poland is avaliable. She recorded R. lepidophyta, Auroraspora versabilis and Aneurospora incohata from the sediments attributed to Latest Devonian. The miospores with multifurcate spines appear somewhat later in the Polish sequence. It is also of interest to note that forms similar to Aneurospora greggsii occur in higher Lower Tournaisian strata probably equivalent to Tn1b age in Turnau's assemblages. On the other hand, the latter form has been reported in profusion from Givetian sediments in Canada and in Upper Devonian of Belgium, U.S.A. and probably from Ireland. A striking difference is in the absence of crassitudinous forms ornamented with distal elements of muri and/or verrucae such as Synorisporites flexuosus and/or S. variegatus sp. nov. One of these forms (if not both) have widely been reported from Upper Devonian of western Europe, U.S.A. and Canada. In north Poland V. vallatus var. hystricosus also occurs in the younger part of the sequence namely in the Lower Tournaisian (Tn1b). The late occurrence of some species in the Polish sediments may be partly facies controlled.

SOVIET UNION: Naumova (1953) investigated miospores from the Upper Devonian of the Russian Platform, and Kedo (1957a, b, 1962, 1963) and Kedo & Goloubtsov (1971) published Upper Devonian palynological results from Pripyat Depression Bielorussia S.S.R. The miospores recorded by these workers have been described in detail in chapter 8, pp.247-49 . In addition to R. lepidophyta, a number of laevigate pseudosaccate miospores identical to the forms described in the present work have also been encountered in the Russian assemblages. Kedo & Goloubtsov (1971) reported the presence of Synorisporites flexuosus as Trachytriletes flexuosus (Jush) from Pripyat Depression Bielorussia. Anchor spined miospores are present in the Soviet assemblages but the forms with multifurcate spines have not been recorded, so far, from the Soviet sediments.

NORTH AFRICA: Recently Massa & Moreau-Benoit (1976) documented Devonian palynology from western Libya. Their assemblages, in the Upper Devonian sediments, are similar to those described from elsewhere. Miospores with multifurcate spines and crassitudinous forms ornamented with verrucae e.g. Synorisporites flexuosus are the common elements. Although neither of these miospore species are illustrated, they are too distinctive to be confused with other forms. Illustrated evidence, from Libyan sediments, of miospores having an equatorial thickening has been provided by Wray (1964, pl. 1, fig. 17). Other ubiquitous forms reported by Massa & Moreau-Benoit (1976) are V. vallatus var. hystricosus, R. lepidophyta and Aneurospora incohata.

AUSTRALIA: Evans (1968), Balme (1962), Balme & Hassell (1962) and more recently Playford (1976) and Playford et al. (1976) recorded miospore assemblages from New South Wales and Australia (western and central). None of these authors reported distinctive

miospores with multifurcate appendages e.g. Ancyrospora multifurcata and/or Hystricosporites multifurcatus and forms similar to Synorisporites flexuosus, S. variegatus sp. nov., Aneurospora greggsii and A. incohata. In addition to the index species R. lepidophyta the Australian workers observed some distinct 'endemic' species including Granulatisporites frustulentus, Apiculatisporis morbis, Convolutispora fromensis, Cirratriradites impensis and Diaphanospora riciniata (see Table 9.1.), the forms which have not been found outside Australia. Cingulate forms with distal thickenings are widely distributed throughout the world. Knoxisporites dedaleus (Naumova) Massa & Moreau-Benoit has been found occurring in the Soviet Union, (Russian Platform and Pripyat Depression) and North Africa (Libya), whereas K. literatus and/or K. pristinus make their appearance elsewhere and also occur in Libya.

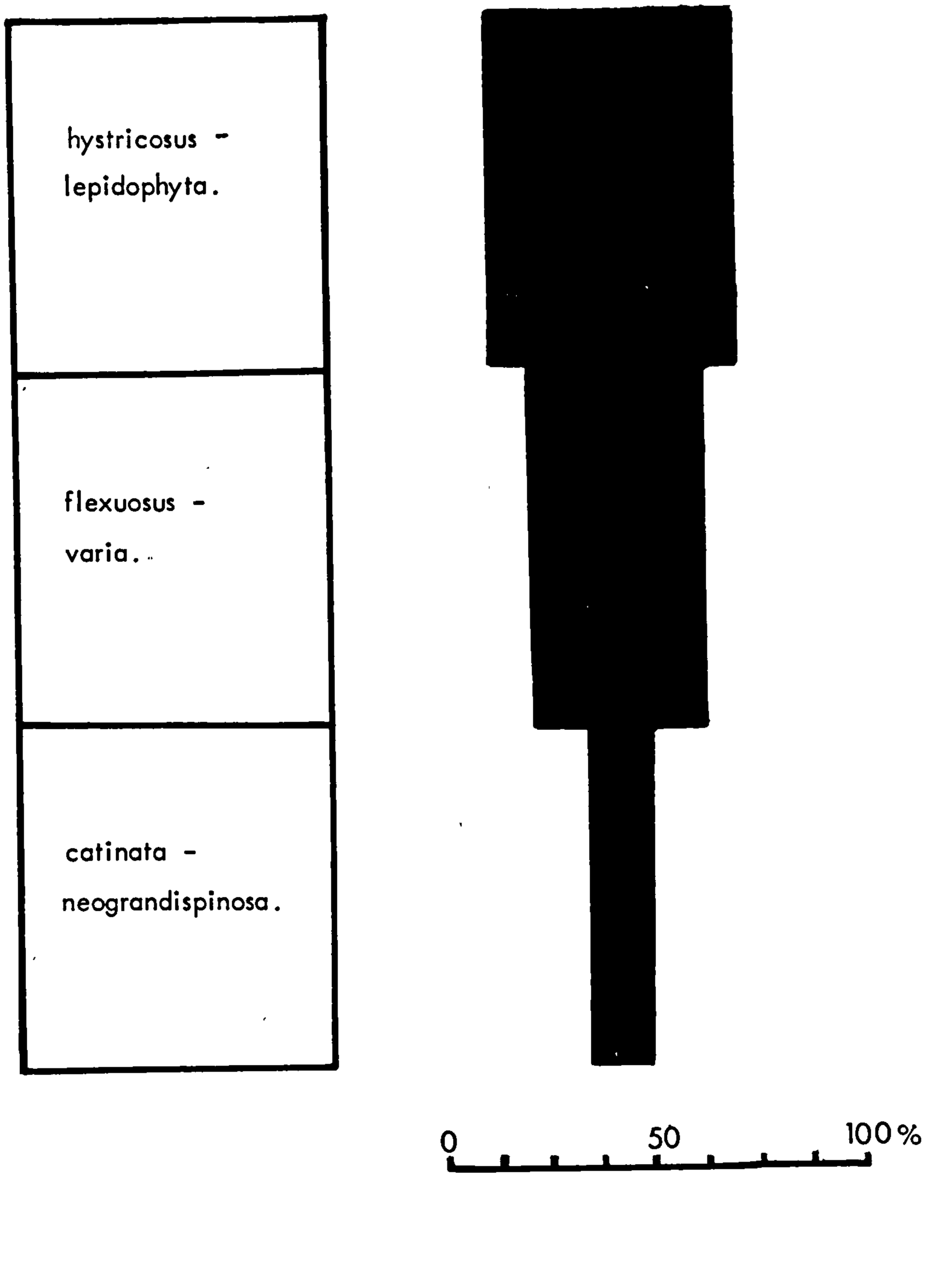
RESULTS AND DISCUSSION

The miospore assemblages that have been reported from the Upper Devonian deposits of Canada, U.S.A., the British Isles, Belgium, Poland and North Africa all have a more or less uniform composition. In other words the miospore records from western Europe and North Africa mirror those of U.S.A. and Canada. The latter are distinguished by the presence of miospores with multifurcate processes, crassitudinous forms with distal murornate and/or verrucate sculptural features, laevigate pseudosaccate species and those miospores possessing 'banded' curvaturae. Typical forms are Synorisporites flexuosus and/or S. variegatus sp. nov., Aneurospora greggsii and A. incohata. Apart from above mentioned elements, and excluding Australia and U.S.S.R., the presence of miospores possessing multifurcate spines seems to be cosmopolitan. Assemblages which fall in this category may be referred to as the

Multifurcata suite because of the widespread and frequent occurrence of miospores with multifurcate spines.

The miospores assemblages recovered from the Soviet regions do not contain any additional species. In fact, these areas are characterized in a negative sense as they do not possess distinctive forms with multifurcate appendages and/or forms with 'banded' curvaturae such as Aneurospora greggsii and A. incohata. It is considered premature to attempt to define these assemblages in terms of a characteristic species. These, therefore, may conveniently be grouped together with those miospore assemblages revealed from Europe, North Africa and North America. Australian miospore assemblages do not contain any of the elements characteristic of the Multifurcata suite. In contrast these are distinguished by the profusely represented endemic form Granulatisporites frustulentus which has not been reported in any of the areas outside Australia, consequently these are referred to as the Frustulentus suite.

As most of the species mentioned above and listed in Table 9.1. are unlimited in their spatial distribution the palaeographical picutre is made indistinct. In conseuqence the evidence does not provide convincing palaeofloristic units. After depicting some floral similarities with the European and Canadian assemblages, Playford (1976, p. 57) considered that there might be significant phytogeographical links between North African (Libyan and Algerian) and Australian miospore contents. Recently evidence has been accrued through palynological investigations conducted by Massa & Moreau-Benoit; the results of investigations into North African miospore assemblages signal that palynologically Australia is probably a distinct continent (see Table 9.1.). Because it is devoid of certain components which are omnipresent in the miospore records of the Upper Devonian strata in the areas lying within the

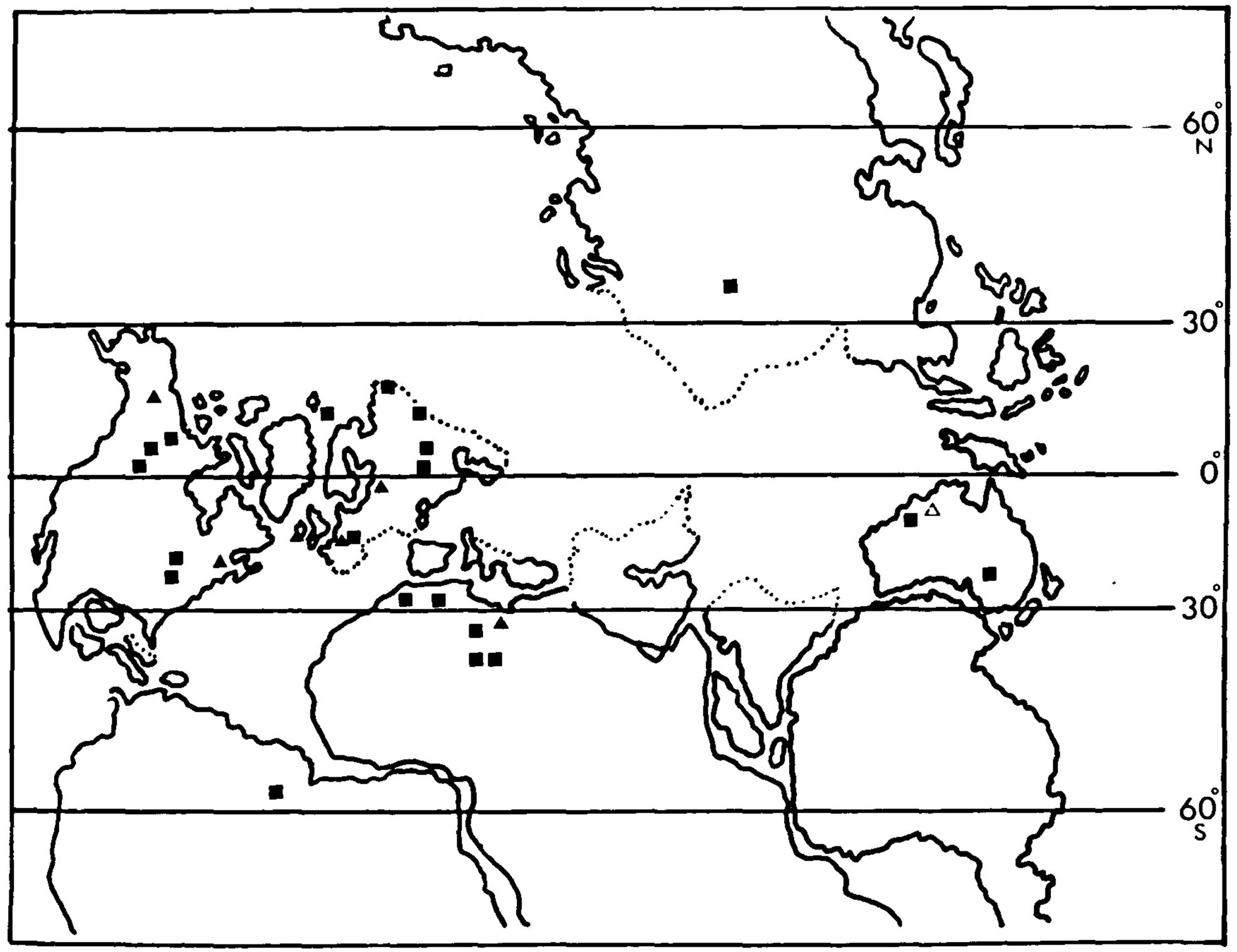


Text fig. 9.1. Proportion of species which typify the Multifurcata suite in the sequence in New York State and Pennsylvania.

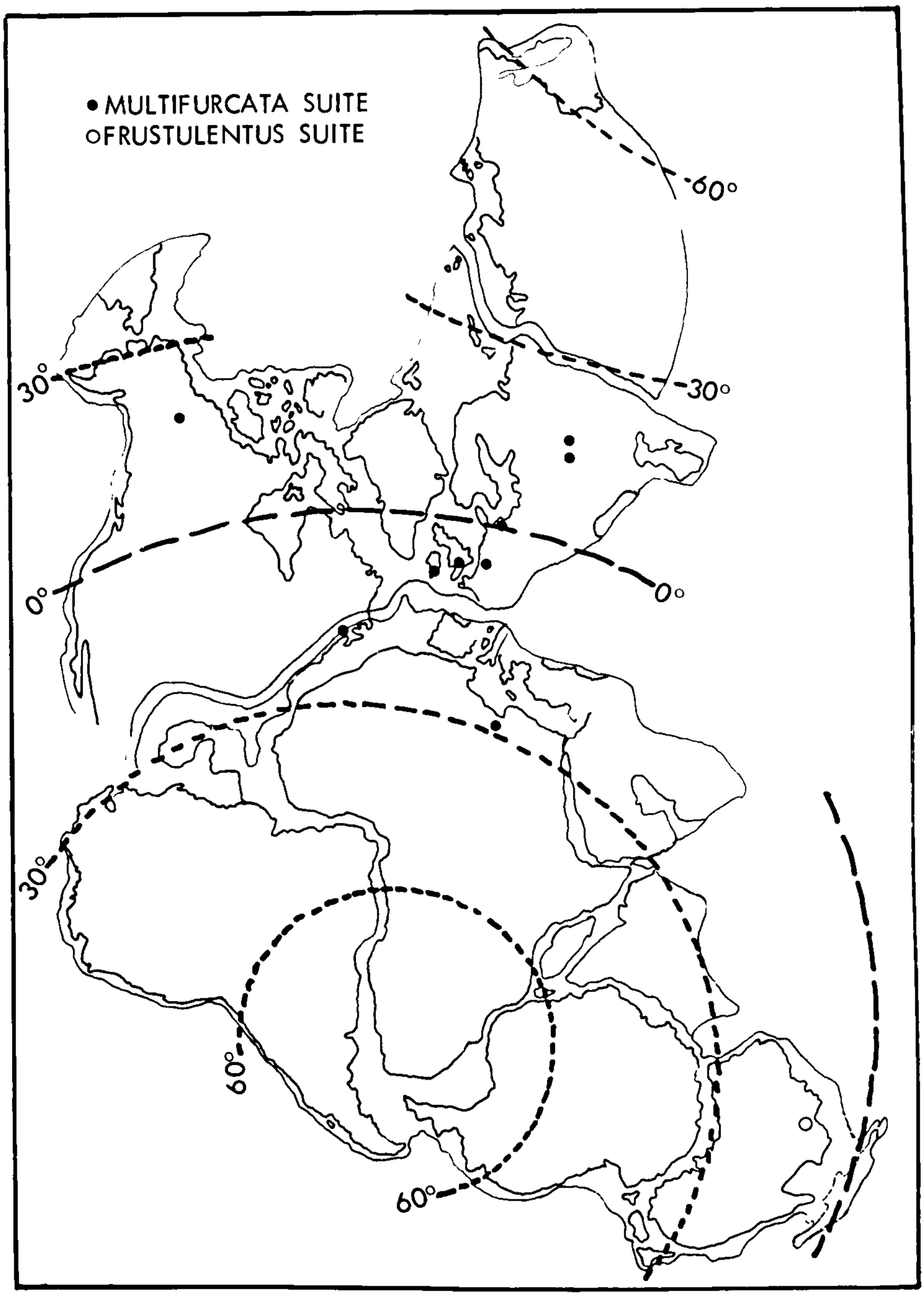
northern hemisphere. However, a minority of indigenous elements in Australian sediments e.g. G. frustulentus, C. fromensis and L. riciniata (see Table 9.1.) is hardly sufficient in the present state of knowledge to warrant the term province. Unless more data on the subject are accumulated, floral province is difficult to delineate.

Geographical and geological links between Africa and North and South America during Palaeozoic have been suggested by various workers. Bar & Riegel (1974) observed close palynological and lithological similarities between the two fragmental parts of ancient Gondwanaland, and therefore Maranhão basin of Brazil was considered as direct continuation of the Ghana coastal regions. On the other hand Streel (1974) remarked upon palynological affinities between North Africa and the Great Lakes region of eastern North America, and suggested probable geographical contiguity during the Upper Devonian.

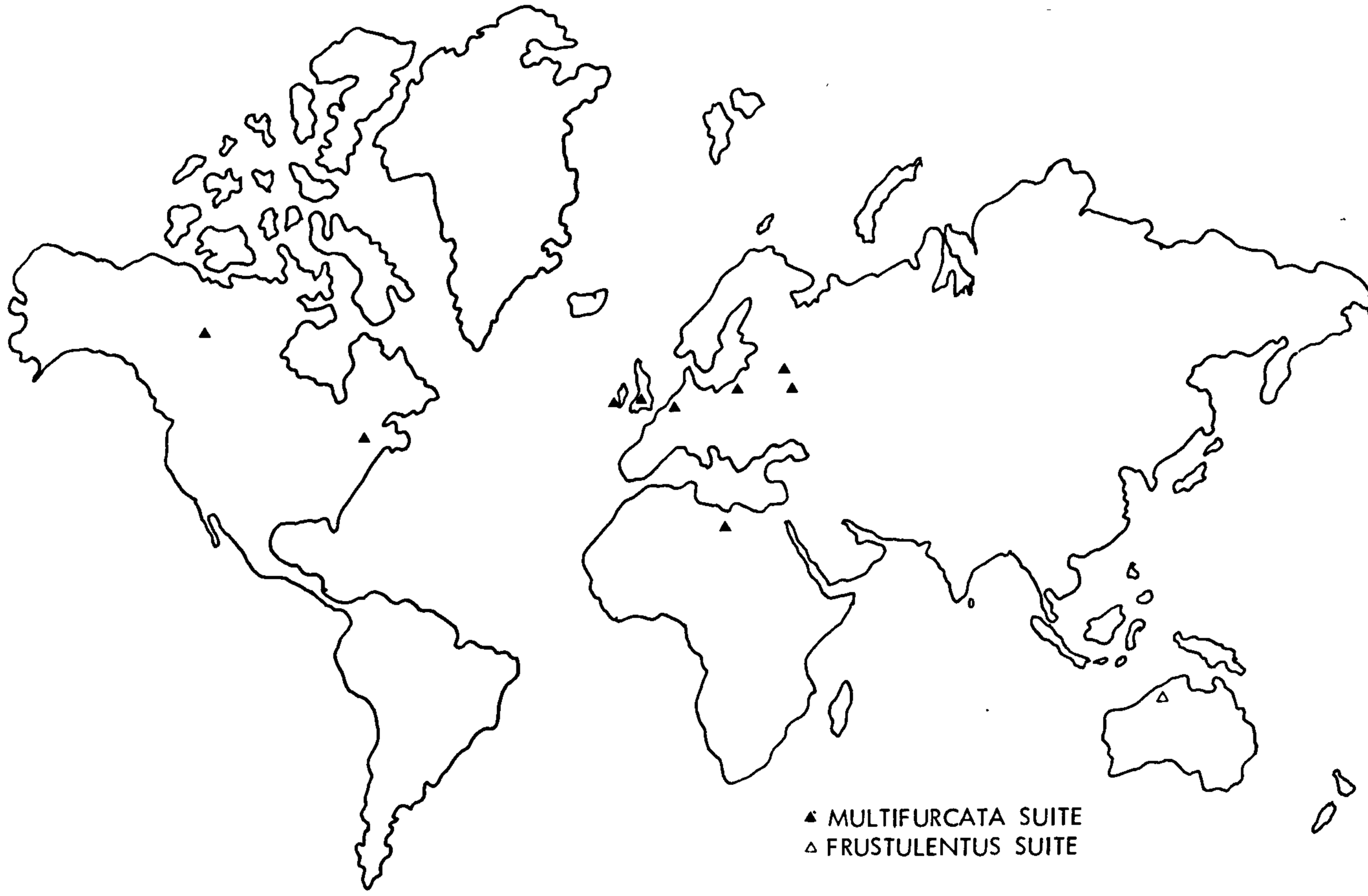
Playford (loc. cit.) went on to suggest that "the Canning Basin microflora connotes a definite provincialism". Streel (1974) also pointed to the possibility of provincialism in Australia. Australian (Famennian) sediments yielded 53 miospore species; of these seven have been recorded during the present investigation. These are Retispora lepidophyta, Knoxisporites literatus, K. pristinus, Auroraspora micromanifesta, Pulvinispora depressa, and probably Hystricosporites prrectus, Punctatisporites solidus (see Table 9.1.). In the writer's opinion widespread occurrence of these species indicates that provincialism in the Upper Devonian is difficult to delineate. The lack of floral provinces may also be attributed to uniformity of environment throughout the world. Inadequate sample coverage may be another reason for the results obtained so far.



Text fig. 9.2. The distribution of the floral suites and R. lepidophyta plotted on the pre-drift continent positions suggested by Smith, Briden, and Drewry (1973) text fig. 11.



Text fig. 9.3. The distribution of the floral suites plotted on the pre-drift continent positions (Middle Devonian) suggested by McElhinney after Oliver 1976.



Text fig. 9.4 The distribution of the floral suites plotted on the present continent positions.

Selected species which occur in the Multifurcata and Frustulentus suites are shown in Table 9.1.. The table is divided into four parts. 1, those species which are usually observed in the Multifurcata suite. 2, species which are typical of the Frustulentus suite. 3, ubiquitous species which frequently make their occurrence in both suites. 4, the miospore forms which occur in the Upper Devonian strata of Ireland and in the present material.

Text fig. 9.I. shows the percentage of species which typify the Multifurcata suite in the studied sequence. It has been observed that there is an increase in the number of species typifying the Multifurcata suite towards the top of the sequences of New York State and Pennsylvania, U.S.A.

A comparison of text fig. 9.4. with Sullivan's 1967 fig. 2 will show that the distribution of the Multifurcata suite more or less approximates that of younger Vallatisporites suite. Thus it would appear that the climatic controls postulated for the regional differentiation of Lower Carboniferous floras were already in operation during the Upper Devonian times.

As with Sullivan's (1965, 1967) Mississippian suites the present Upper Devonian floral suites also lie in belt approximately parallel to the palaeolatitude.

CONCLUSIONS.

The palynological floras of marine and non-marine sediments of western New York State and northern Pennsylvania contain a diversity of trilete spores, together with an acritarch component that is relatively inconspicuous qualitatively and quantitatively.

Based on qualitative changes in the spore assemblages, it is possible to distinguish three successive zones. Each zone derives its name from two distinctive species which appear at the base of zone and are from base upwards: the Streelispora catinata - Ancyrospora neograndispinosa, ranging from late Frasnian to late Famennian, the Synorisporites flexuosus - Auroraspora varia, zone of middle Famennian and the Vallatisporites vallatus var. hystricosus - Retispora lepidophyta, zone of late Famennian Fa2d.(see Table 8.1.)

External correlation is afforded by the strikingly close similarity between the microfloras described herein and those reported previously from the Upper Devonian of other parts of the world. Detailed correlation of these Famennian deposits with those from North America, North Africa, western Europe and Australia shows that V. vallatus var. hystricosus and R. lepidophyta appear in the same horizon in Famennian (approximately at the base of Fa2d) in the area investigated as in other sequences so far described from nothern and southern hemispheres. Inter-regional correlation based on miospore assemblages has indicated that the Dexterville Member is equivalent to the Evieux beds; whilst the Ellicott Member and overlying Cattaraugus Formation are probably coeval stratigraphically to the Comblain-Au-Pont beds of Belgium (see Chapter 8, pp. 242-3). In terms of Belgian substages, the age of the strata investigated is shown tc range from F3 to Fa2d (Upper Frasnian to middle Famennian in terms of standard European stages). In terms of North American nomenclature, the series range in age from Upper Senecan to Chautauquan.

In the samples from the Bush Hill Section no acritarchs or chitinozoa have been found and, since these microfossils are often abundant in brackish and marine sediments, their absence strongly support the prevalent view that the sediments of the Bush Hill Section were laid down in continental regime.

Marine and non-marine facies may contain many species in common. In the Upper Devonian of New York State and Pennsylvania, this phenomenon has been observed in the marine Ellicott Member of the Chadakoin Formation and in the lower part of the non-marine Ellicott Member of the above mentioned formation, which have most species in common and concluded to be coeval (see pp. 230).

In marine facies miospores range from 5 to 90 per cent. ; whilst in continental strata they are hundred per cent. of the total assemblages. The occurrence of acritarchs is surprisingly erratic and range from 2 to 74 per cent. (see Text fig. 7.I.).

Aneurospora greggsii is the most numerous component in some of the samples of the present study. This is especially true in sequences in the lower part of the Ellicott Member of the Chadakoin Formation where the population of A. greggsii ranges from 30 to 43.5 per cent. In the assemblages of the overlying Cattaraugus Formation this taxon declines in abundance to only one per cent. or less of the total assemblages. This species is most abundant in the continental strata e.g. the Bush Hill Section, whilst in marine facies its numbers are reduced. The abundance of A. greggsii in sediments of siltstone and fine sandstone can be correlated with the presence of sporangia containing this spore species (see p.97 of systematic and pl. 3, figs. 2 and 3.). In many of the samples, however, Streelispora catinata is by far the most abundant species ranging from 10 to 20 per cent. The species Auroraspora torquata is also common and ranges from 5 to 10 per cent. in many samples. A miospore with multifurcate spines, Ancyrospora multifurcata is relatively abundant in certain

samples namely the siltstone from the Bush Hill, Brick Quarries (the Dexterville Member) and Walnut Creek Sections. It is persistent component in both marine and non-marine facies, in other samples it is relatively rare (less than one per cent.) or absent.

The species Synorisporites flexuosus has frequently been observed in younger part of the sequences investigated. It has been found in almost all the samples of younger two assemblage zones namely the FV and HL. The species could be considered as an index fossil of middle Famennian (Fa2b - Fa2c), since it has been reported from almost equivalent stratigraphical levels in many parts of the world e.g. western Europe, North Africa and North America.

The miospore species of the genus Auroraspora have been found from throughout the sequences. In particular, the samples from Bush Hill Section yielded well preserved and many forms of the above mentioned genus. It is evident from Table 7.I. and Text fig. 6.9. that there is a gradual increase (quantitative and qualitative) in different forms of the genus Auroraspora from bottom to top of the sequences investigated. The CN zone is characterized by only two species; whilst in the overlying FV zone eight species of Auroraspora have been recorded. The total number of Auroraspora species is eight in the youngest HL zone. In consequence, eighteen species (forms) of the genus Auroraspora have been arranged stratigraphically and are considered to be related morphologically (see pp.193-7). It is worth mentioning that the palynological assemblage obtained from material from the Bush Hill Section is excellently preserved, when compared with the nature of preservation in other parts of the sequences. The miospores of the genus Auroraspora recorded from the Bush Hill material exhibit conspicuous pattern of coarse radial folding on the pseudosaccus.

The Upper Devonian miospore assemblages that have been reported from western Europe, North America and North Africa are found to have a uniform composition and are referred to as the Multifurcata suite in this study.(see Chapter 9, pp.271-8). The miospore species that are regarded to be ubiquitous to the Upper Devonian sediments of northern and southern hemispheres include R. lepidophyta, V. vallatus var. hystricosus, K. literatus, K. pristinus, A. micromanifesta and P. solidus (see Table 9.I.). While the Upper Devonian miospore species of Australia are identifiable with taxa recorded from northern and southern hemisphere sequences, some are clearly endemic to the Australian sediments. Of the latter G. frustulentus, C. fromensis, C. impensis, H. scorpius, D. reciniata and L. laurensis are particularly noteworthy. The first named miospore (G. frustulentus) is the most abundent and persistent of the endemic forms of the Australian miospores. Consequently the miospore assemblages reported from Australia are referred to as the Frustulentus suite in this study.

Indeed the present study endorses and strengthens the view expressed by Playford (1976, p. 58) that ''in terms of phytogeography the Cannin Basin microflora connotes a definite provincialism .....'' Apart from microflora fauna also provide a positive evidence concerning the endemism in the Upper Devonian of Australia. Playford (loc. cit. p. 57) further writes that ''Bruce & Nicoll (in prep.) find that the Fairfield conodont fauna contain a rather substantial component of endemic forms!'.

Two of the problems arising from this study are, how such a cosmopolitan spore flora could exist whereas provinces apparently existed in the Lower Carboniferous, and secondly why there are some differences in the Australian Upper Devonian.

EXPLANATION OF PLATES

All figures are from unretouched negatives and prints. Magnifications are X500, unless stated otherwise. Transmitted light photographs were taken with Zeiss Photomicroscope under bright-field illumination. Ilford Pan-F film was used.

Scanning electron micrographs, indicated by the letters SEM, were taken with Cambridge Stereoscan scanning electron microscope, using Kodak Tri-X film.

PLATE I

Fig. I. *Calamospora liquida* Kosanke.

US6B 280 I269268. Cattaraugus Fm.

Fig. 2. *Calamospora nigrata* (Naumova) Allen.

US6E 299 I228589. Cattaraugus Fm.

Figs. 3-4. *Calamospora pedata* Kosanke.

3. US8D 357 I24850I. Ellicott Member.

4. NY96A 39 II33069. Ellicott Member.

Fig. 5. *Leiotriletes ornatus* Ishchenko.

NY95C 38 I218463. Cattaraugus Fm.

Fig. 6. *Leiotriletes tortilus* Playford.

USI2Z I73 I2II299. Laona Siltstone Member.

Fig. 7. *Punctatisporites glaber* (Naumova) Playford.

NY96C 57 I098524. Ellicott Member.

Figs. 8-9. *Punctatisporites minutus* Kosanke.

8. US8C 352 II76582. Ellicott Member.

9. US6E 297 II29049. Cattaraugus Fm.

Figs. I0-II. *Punctatisporites platirugosus* (Waltz) Sullivan.

I0. US8B 345 II39536. Ellicott Member.

II. US8D 355 II9I388. Ellicott Member.

Fig. I2. *Punctatisporites solidus* Hacquebard.

NY95A II I20I696. Cattaraugus Fm.

Fig. I3. *Punctatisporites stabilis* Playford.

USIOB 38I II82449. Northeast Shale Member.

Figs. I4-I9. *Retusotriletes caperatus* sp. nov.

I4. US8A 332 I2I2329. Ellicott Member.

I5. Holotype, US6E 300 III649. Cattaraugus Fm.

I6. Detail of holotype, X I000.

I7. NY95B 22 I2I2345. Cattaraugus Fm.

I8. US6C 288 I25159I. Cattaraugus Fm.

I9. US6C 289 II0860I. Cattaraugus.Fm.

PLATE 1

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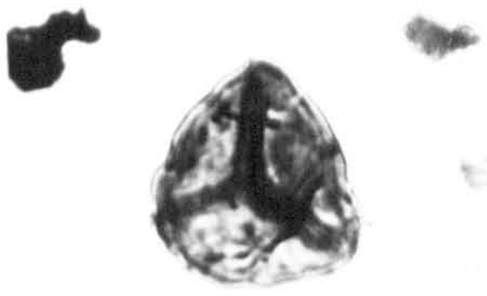
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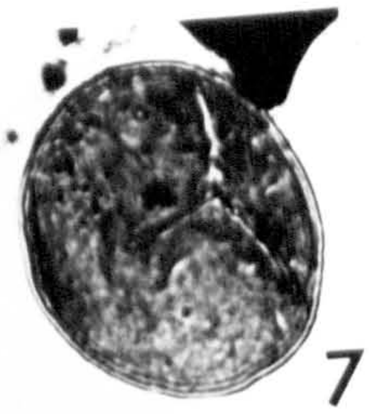
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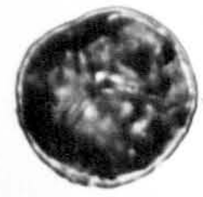
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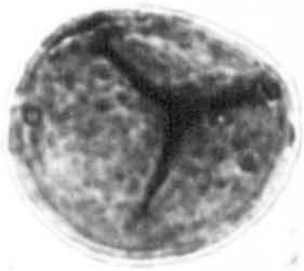
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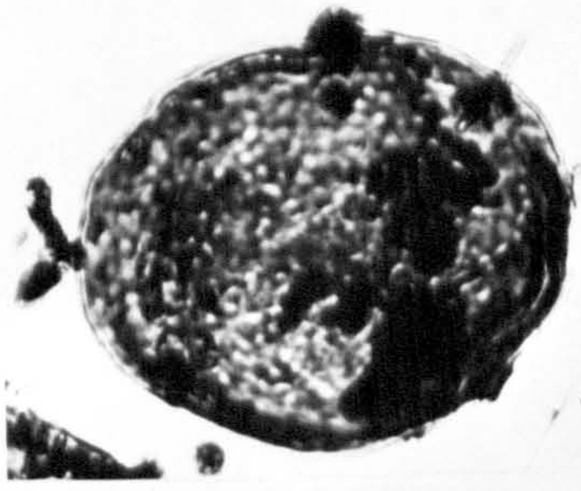
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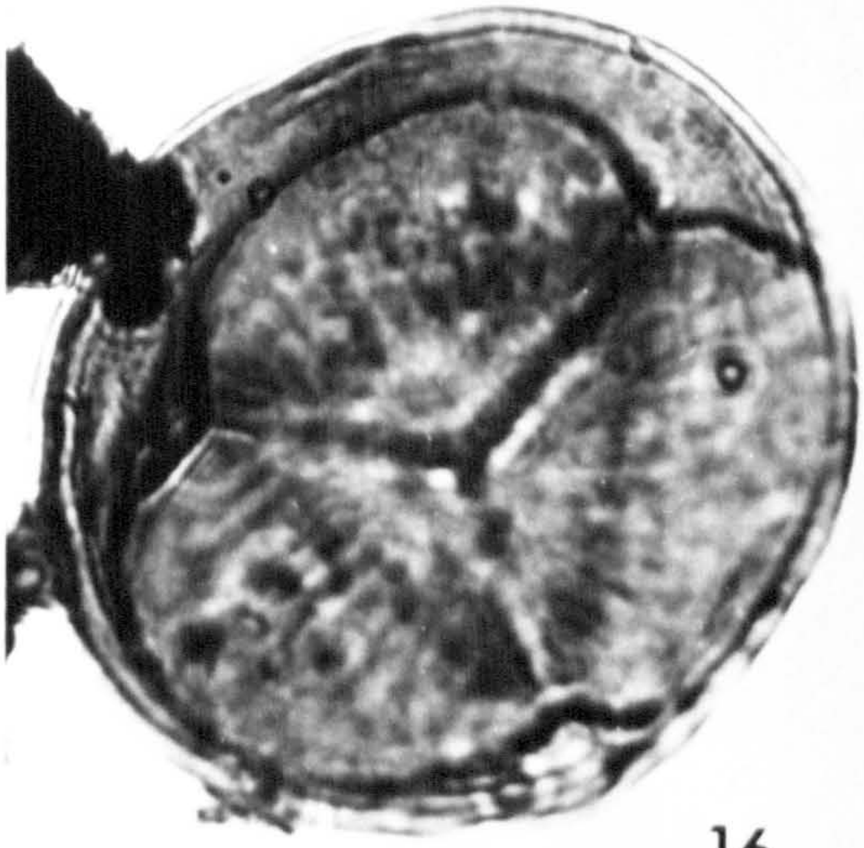
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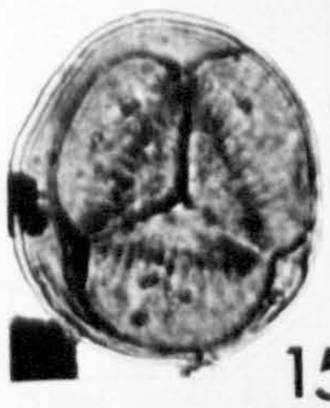
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PLATE 2

Figs. I-3. Retusotriletes cf. concinus Kedo in Lanninger.

I. NY96A 79 I228587. Ellicott Member.

2. NY96A 76 II9804I. Ellicott Member.

3. NY96A 79 II08549. Ellicott Member.

Fig. 4. Retusotriletes goensis Lele & Streel.

US8A 332 I2I8644. Ellicott Member.

Fig. 5. Retusotriletes concretus nom. nov.

NY96C 74 III0032. Ellicott Member.

Figs. 6-7. Retusotriletes sp.

6. US8A 338A II59309. Ellicott Member.

7. US8A 338A II00048. Ellicott Member.

Fig. 8. Apiculiretusispora fructicosa Higgs.

NY96D 96 I080699. Ellicott Member.

Figs. 9-II. Apiculiretusispora plicata (Allen) Streel.

9. US6D 296 I232338. Cattaraugus Fm.

I0. US6D 295 II8926I. Cattaraugus Fm.

II. Detail of I0, X I000.

Fig. I2. Pulvinispora depressa Balme & Hassell.

US6E 299 I260049. Cattaraugus Fm.

Fig. I3. Pulvinispora quasilabrata Higgs.

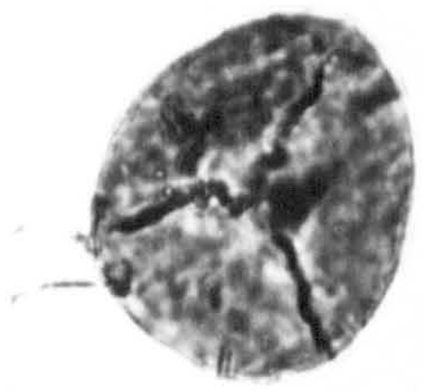
US6E 300 II04034. Cattaraugus Fm.

Figs. I4-I5. Aneurospora greggsii (McGregor) Streel.

I4. NY96D 96 II04328. Ellicott Member.

I5. Distal focus, detail of I4, X I000.

PLATE 2



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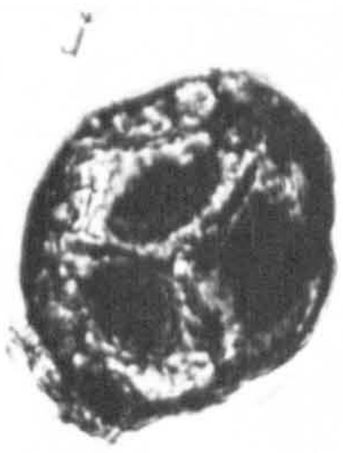

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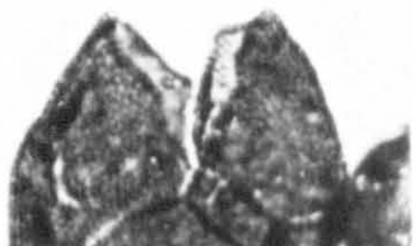

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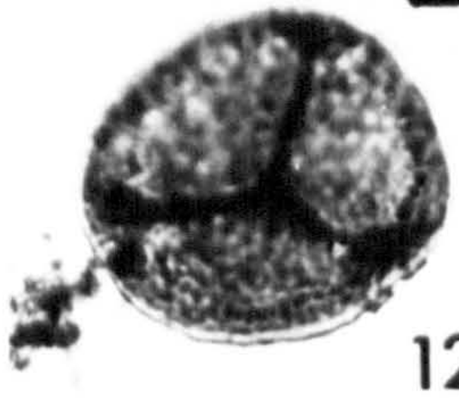

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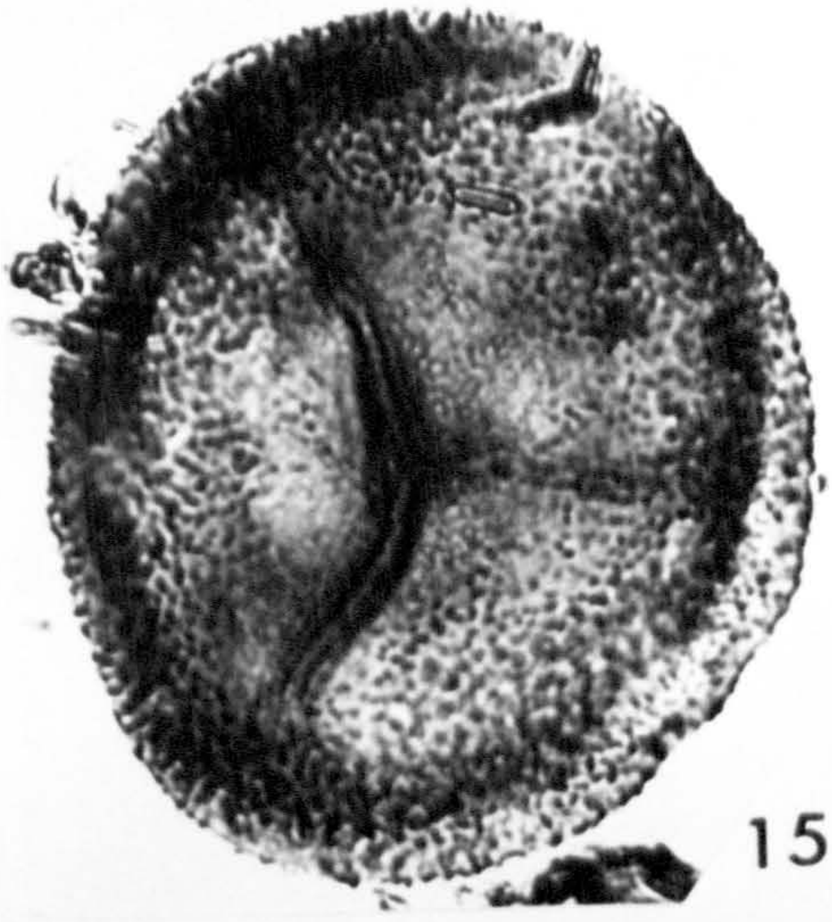

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PLATE 3

Figs. I-8. Aneurospora greggsii (McGregor) Streel.

I. Proximal focus, NY96D 96 II04328, X 1000.

2. A cluster of A. greggsii,
NY96C 74C II57638. Ellicott Member.

3. NY96C 74C I2026II. Ellicott Member.

4. NY96H I48 II82407. Ellicott Member.

5. NY96D 96 II08324. Ellicott Member.

6. US6D 296 I250699. Cattaraugus Fm.

7. NY96C 74C I220065. Ellicott Member.

8. Detail of 7, X I000.

Fig. 9. Aneurospora incohata (Sullivan) Streel.
Proximal focus, US8A 33I II80064,
Ellicott Member.

Fig. IO. Geminospora lemurata Balme.
US8D 357 III8068. Ellicott Member.

Figs. II-I3. Aneurospora greggsii var. minuta var. nov.

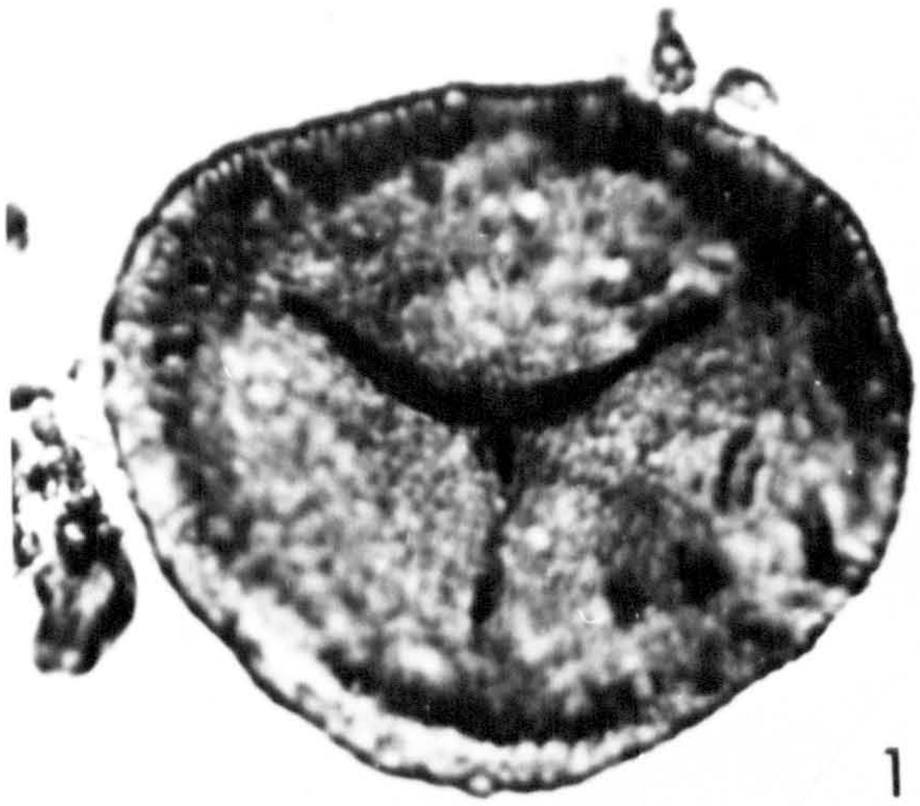
II. NY96H I48 I20I424. Ellicott Member.

I2. NY96C 74B I225369. Ellicott Member.

I3. NY96C 74 III0068. Ellicott Member.

Fig. I4. Verrucosisporites maculosus Artuz.
NY96C 74C I262329. Ellicott Member.

PLATE 3



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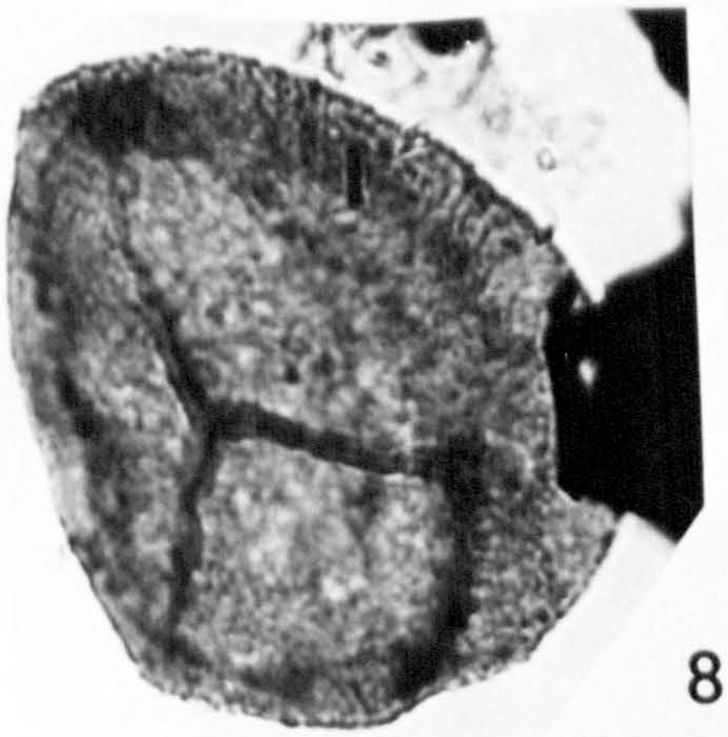

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PLATE 4.

Figs. I-4. Verrucosisporites microtuberosus (Loose) Smith & Butterworth.

I. NY96H 146 1250439. Ellicott Member.

2. Detail of I, XI000.

3. NY96B 87 II00362. Ellicott Member.

4. Detail of 3, XI000.

Figs. 5-6. Acanthotriletes horridus var. minutus var. nov.

5. US4A I9 I2404I2. Dexterville Member.

6. US4A I9 I090602. Dexterville Member.

Fig. 7. Acanthotriletes sp.

US4F 245 I254688. Dexterville Member.

Figs. 8-9. Dibolisporites sp.

8. NY96G I38 II69434. Ellicott Member.

9. Detail of 8, XI000.

Fig. I0. Raistrickia ampullacea Hacquebard.

NY96C 74C I249308. Ellicott Member.

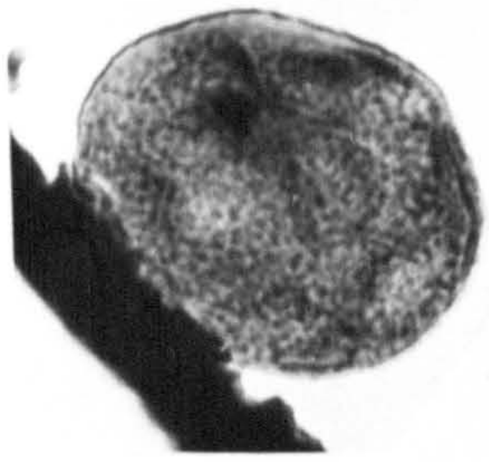
Fig. II. Raistrickia baculosa Hacquebard.

NY96C 74C I25I324. Ellicott Member.

Fig. I2. Raistrickia cf. clavata Hacquebard emend. Playford.

NY96A 78 III06I. Ellicott Member.

PLATE 4



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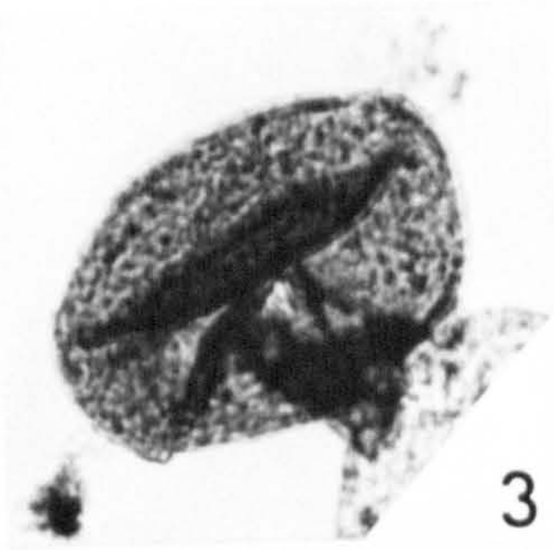

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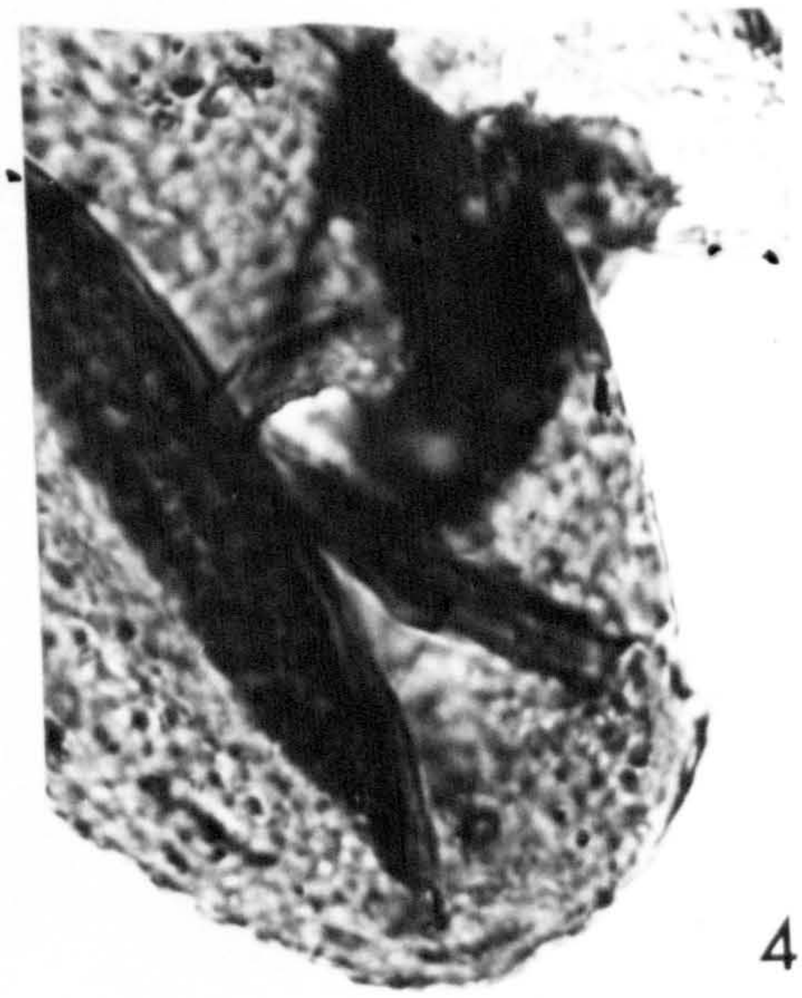

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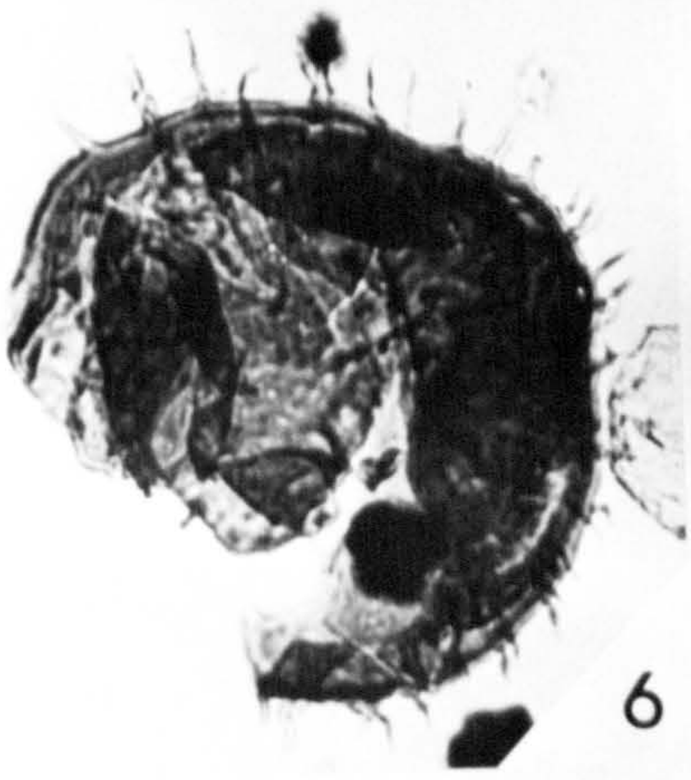

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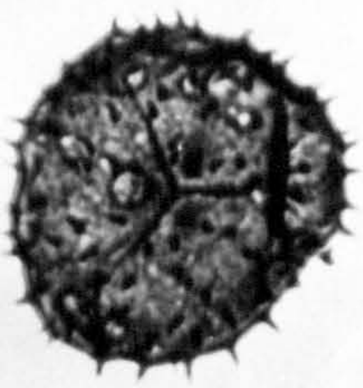

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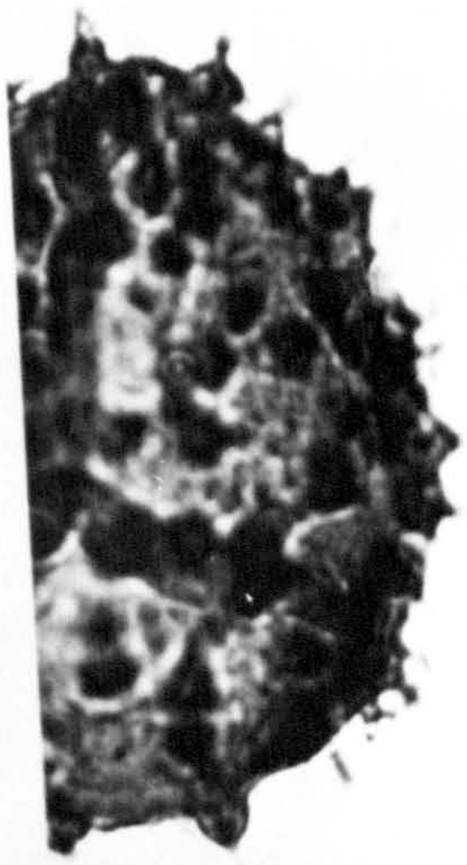

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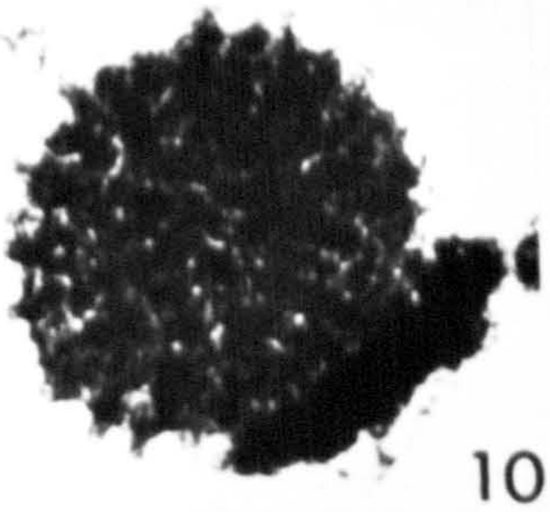

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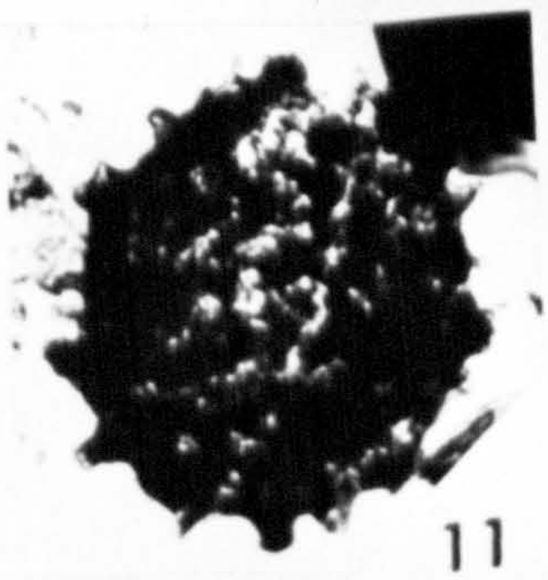

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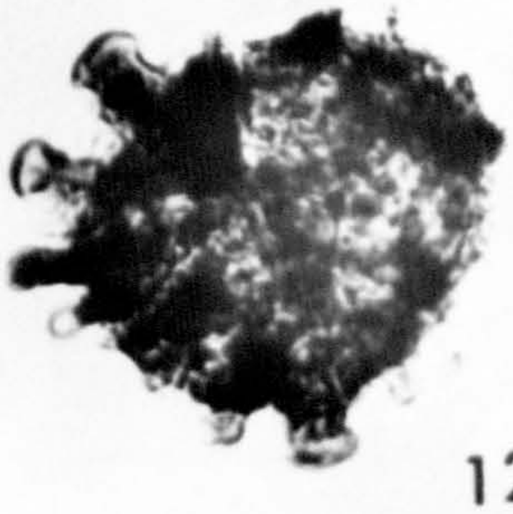

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PLATE 5

Figs. I-4. Biharisporites parviornatus Richardson.

I. NY96C 74B I223038, X300, Ellicott Member.

2. Detail of I, X 500.

3. NY96A 28 II65496, X 300, Ellicott Member.

4. Detail of 3.

Fig. 5. Camptotriletes verrucosus Butterworth & William.

USIOB 384 II2I035. Northeast Shale Member.

Figs 6-8. Convolutispora definita sp. nov.

6. Holotype, NY96H I46 I068688. Ellicott Member.

7. NY96B 90 II42394, Ellicott Member

8. NY96C 74C II4055I, Ellicott Member

Figs. 9-IO. Convolutispora mellita Hoffmeister, Staplin & Malloy.

9. NY96H I48 II42060. Ellicott Member.

IO. US6E 299 II32375. Cattaraugus Fm.

PLATE 5

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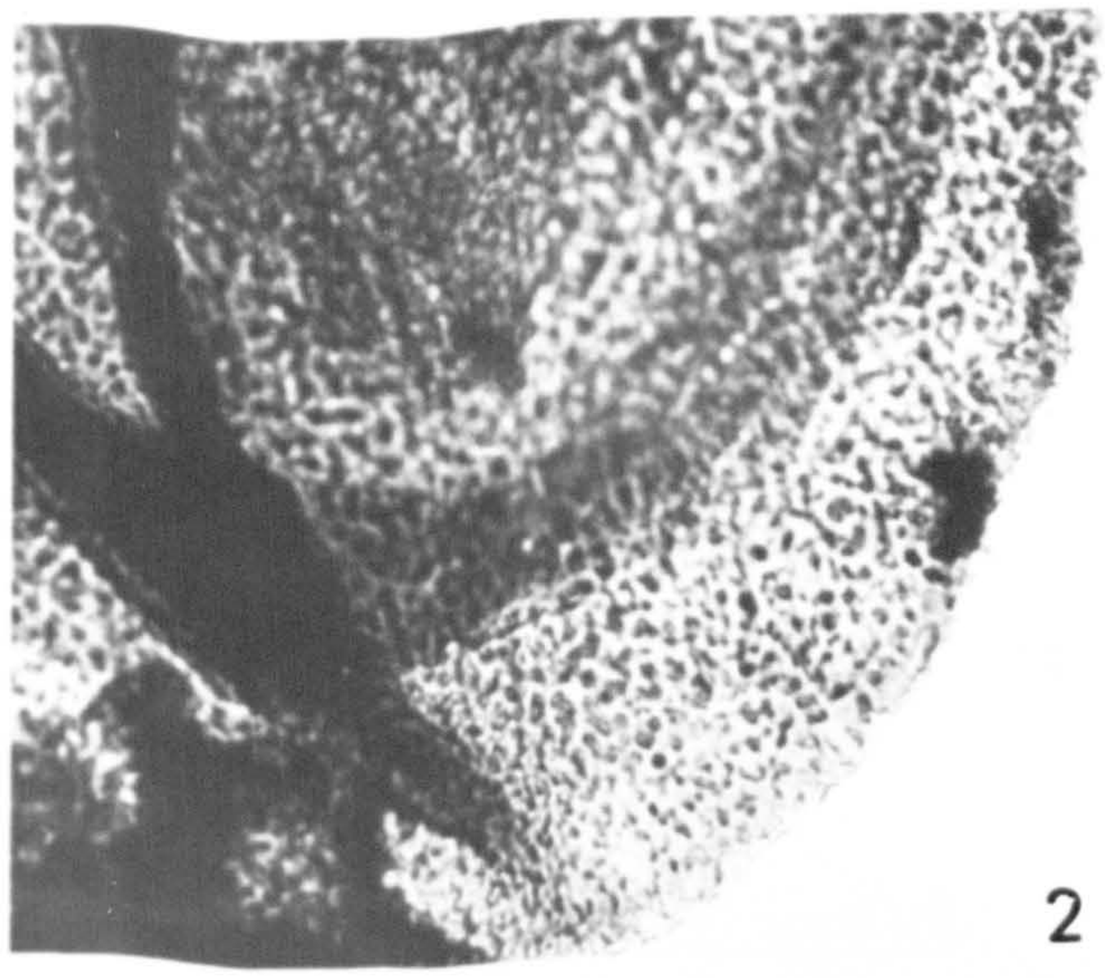

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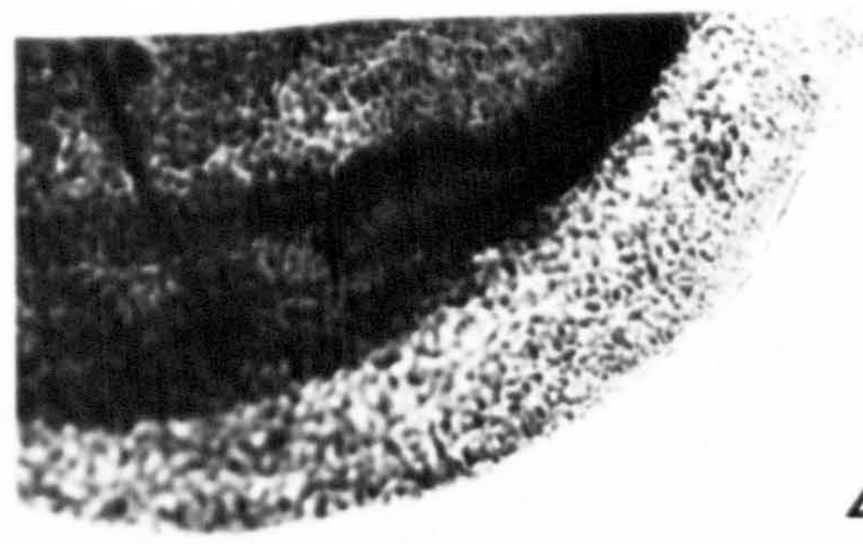

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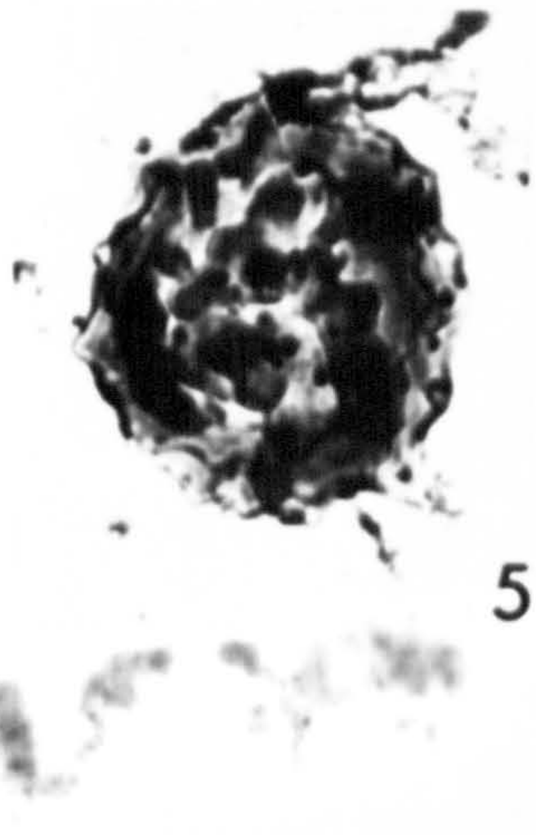

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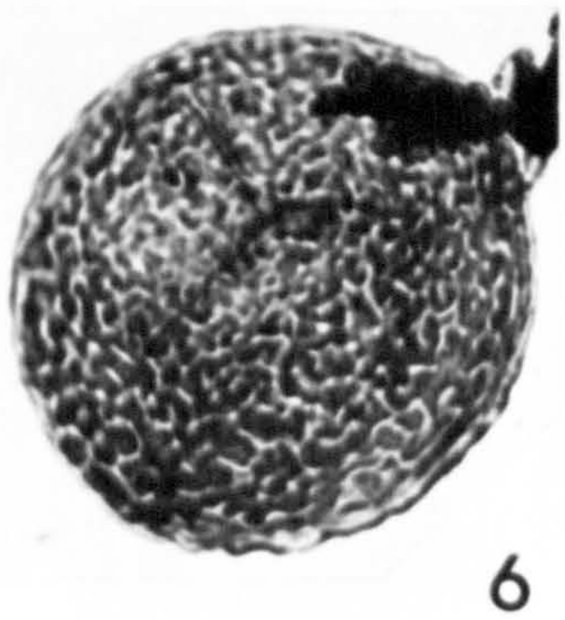

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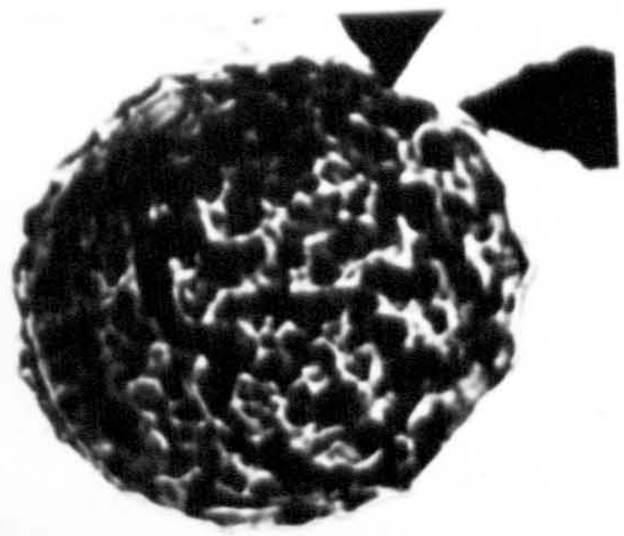

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PLATE 6

Figs. I-3. Convolutispora vermiformis Hughes & Playford.

I. IOB 376 II62432. Northeast Shale Member.

2. IOB 38I II99558. Northeast Shale Member.

3. US6E 302 I240415. Cattaraugus Fm.

Fig. 4. Convolutispora sp. aff. verrucosisporites congestus Playford.

IOB 38I II45596. Northeast Shale Member.

Fig. 5. Emphanisporites cf. annulatus McGregor.

US6D 293 I2I8648. Cattaraugus Fm.

Figs. 6-9. Emphanisporites rotatus McGregor.

6. US6D 293 II8I4I6. Cattaraugus Fm.

7. USI2M I38 II6I48I. South Wales Shale Member.

8. US6E 299 I245459. Cattaraugus Fm.

9. Specimen showing folds along laesurae, NY96C 74C II2033. Ellicott Member.

Fig. IO. Dictyotriletes cf. trivialis Kedo.

US8D 357 I252478. Ellicott Member.

Fig. II Dictyotriletes sp.

US6A 267 I2I0047. Cattaraugus Fm.

PLATE 6

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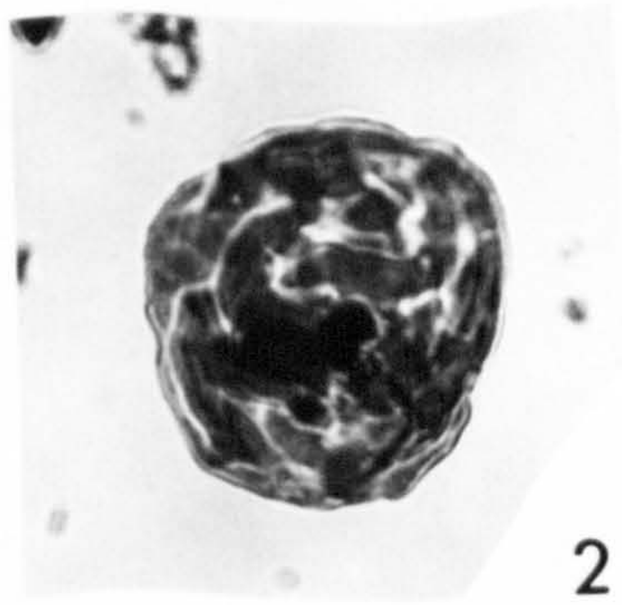

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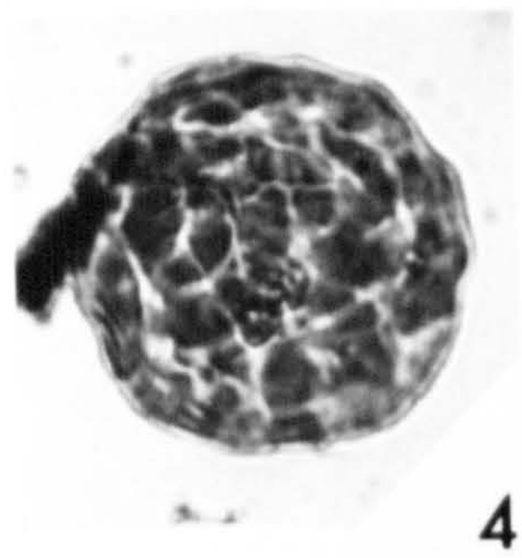

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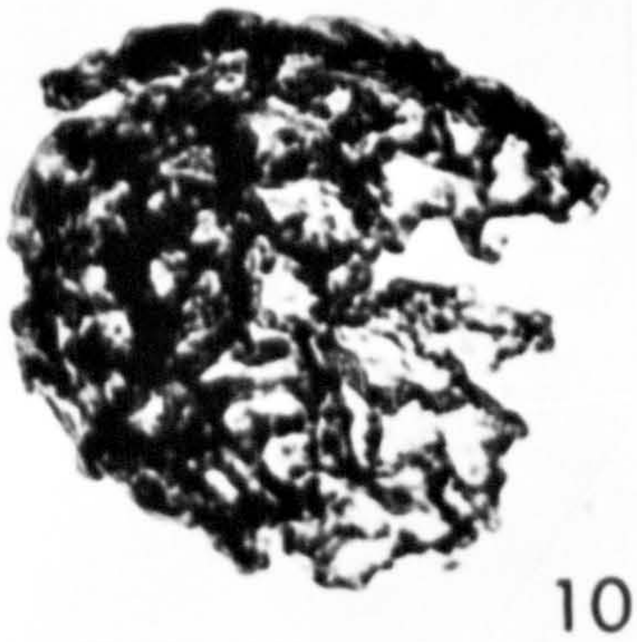

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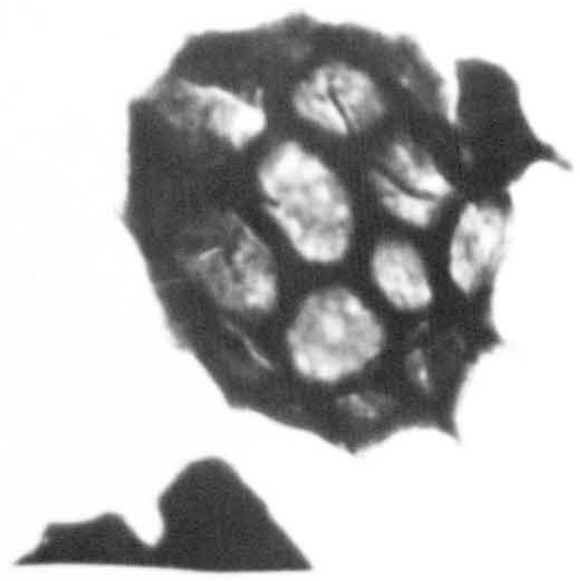

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PLATE 7

Figs. I-2. Knoxisporites literatus (Waltz) Playford.

I. NY96C 73 II18335. Ellicott Member.

2. NY96C 74C I180505. Ellicott Member.

Figs. 3-4. Knoxisporites pristinus Sullivan.

3. NY96C 74C I22I482. Ellicott Member.

4. US 6H 3I9 I200588. Dexterville Member.

Fig. 5. Knoxisporites sp. aff. Reticulatisporites crassus Winslow.

NY96B 86 II32585. Ellicott Member.

Figs. 6-7. Lophozonotriletes curvatus Naumova.

6. NY96C 74C II90379. Ellicott Member.

7. Detail of 6, X I000.

Figs. 8-II,I3. Vallatisporites vallatus var. hystricosus (Winslow) Clayton et. al.

8. US95A II I090531. Cattaraugus Fm.

9. US6H 3I9 II98592. Cattaraugus Fm.

I0. US6G 3I4 I090060. Cattaraugus Fm.

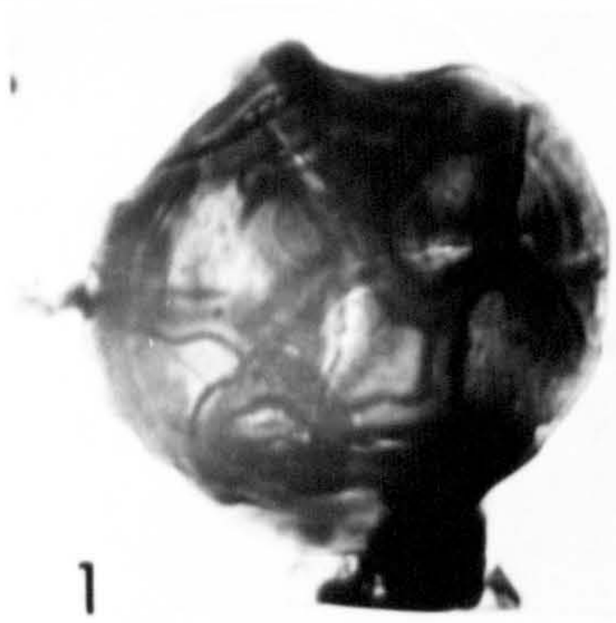
II. NY95A II II60462. Cattaraugus Fm.

I3. Distal surface, NY96A, SEM, X II00. Ellicott Member.

Fig. I2. Vallatisporites vallatus var. major (Kedo) comb. nov.

US6B 280 I090694. Cattaraugus Fm.

PLATE 7



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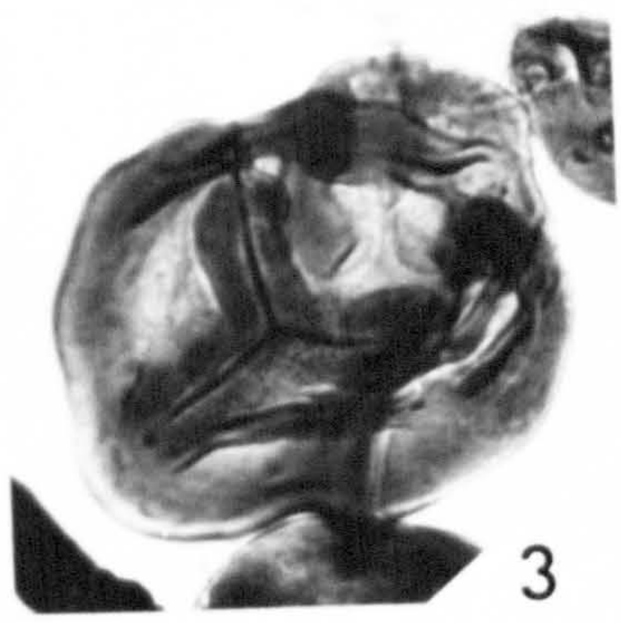

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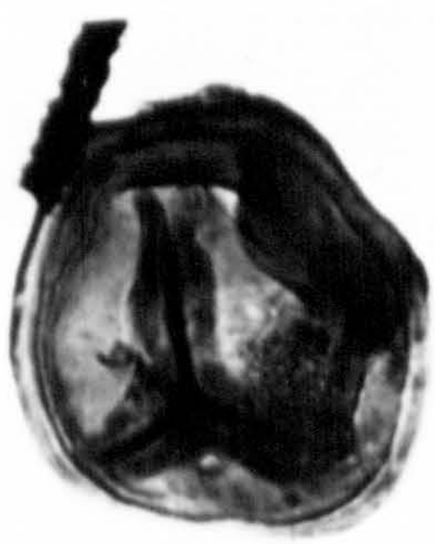

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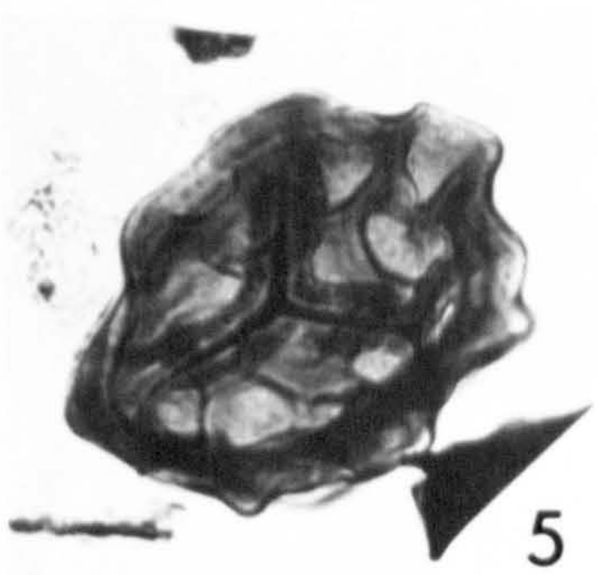

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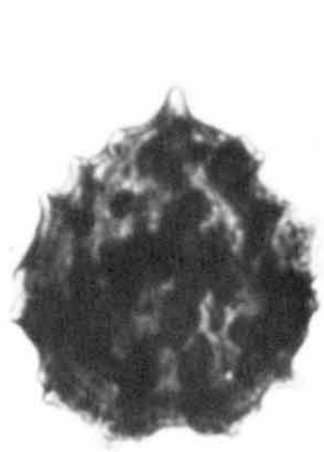

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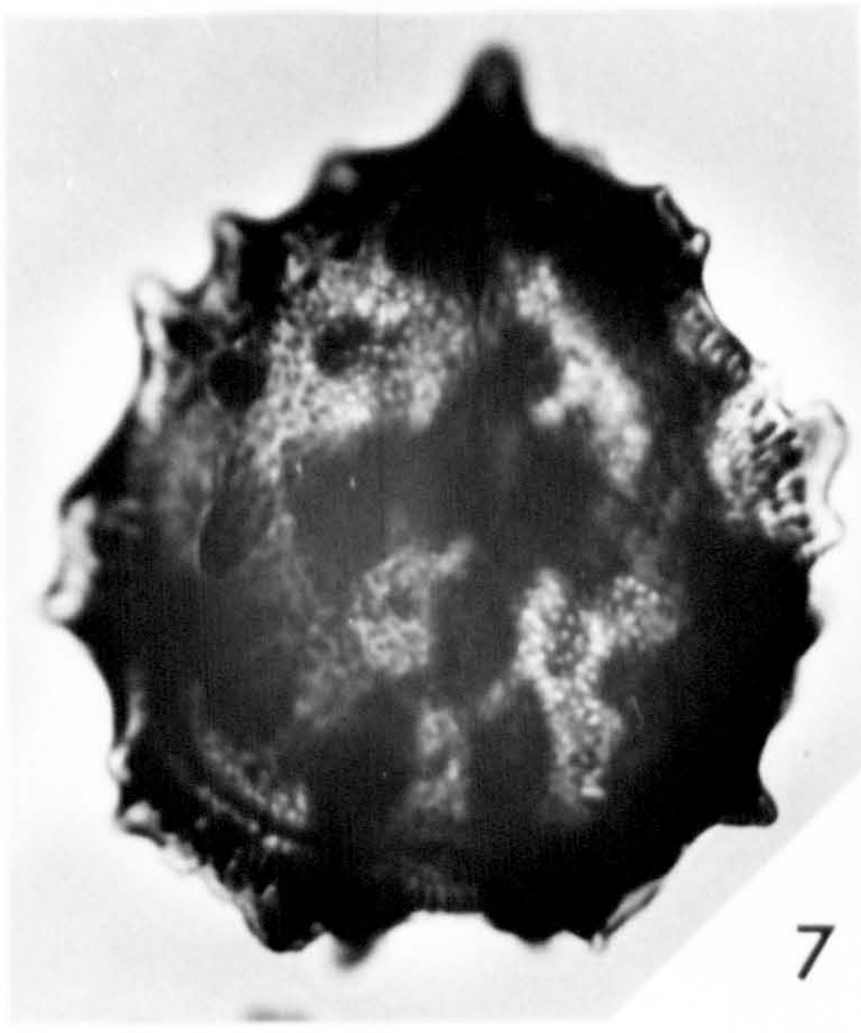

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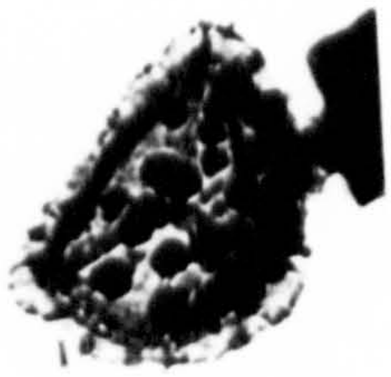

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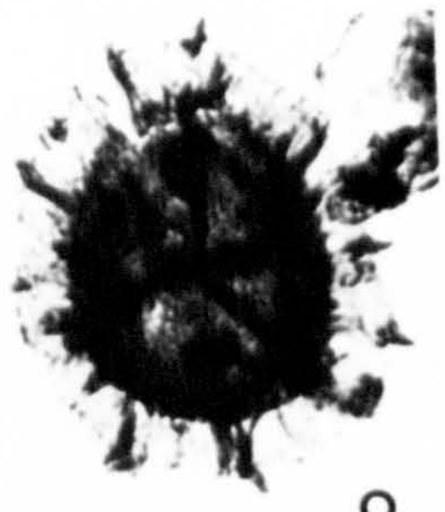

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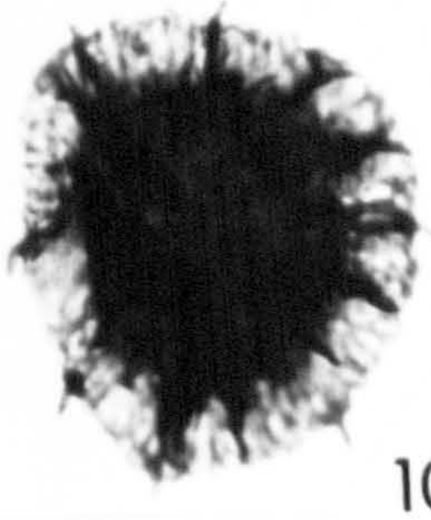

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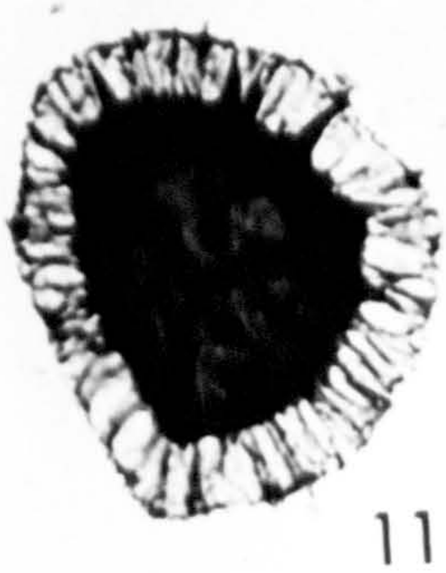

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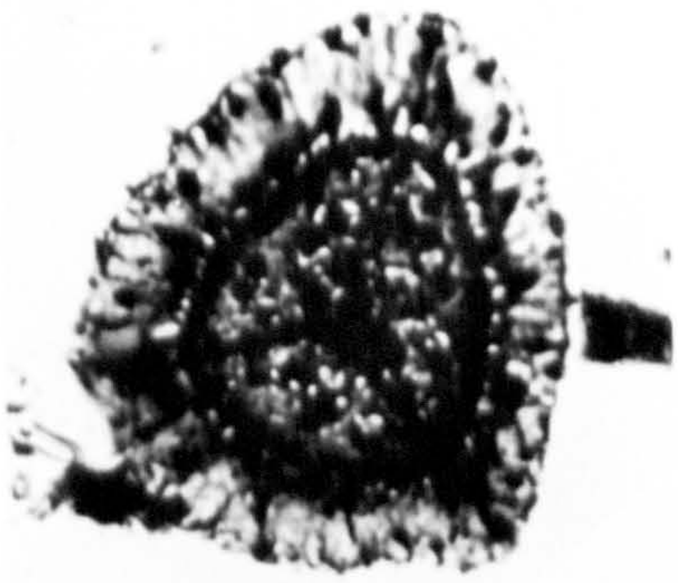

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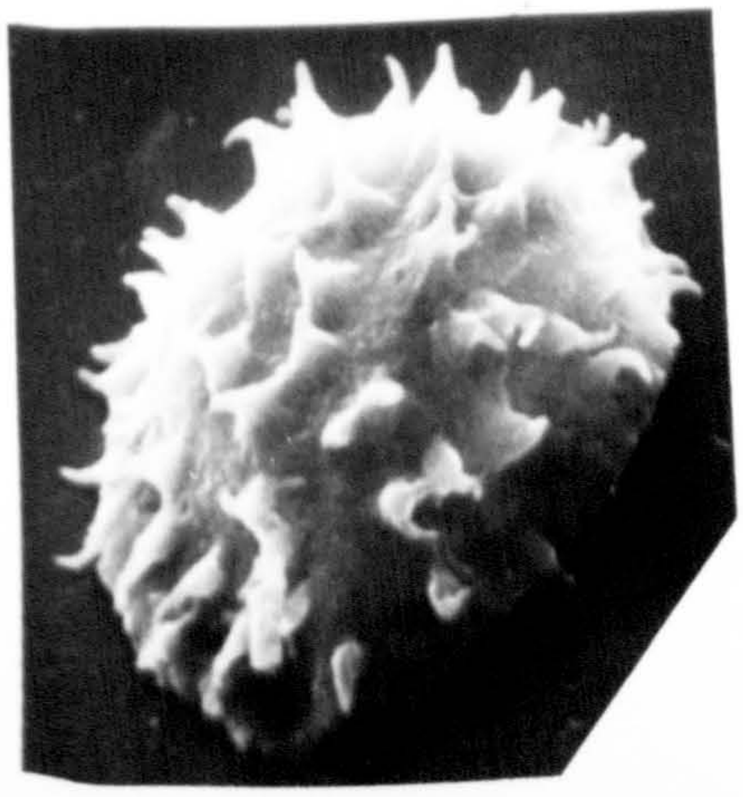

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PLATE 8

Figs. I-2. Ambitisporites cf. avitus Hoffmeister.

I. NY95A II I09646I. Cattaraugus Fm.

2. NY95C 36 II0I05I. Cattaraugus Fm.

Figs. 3-4. Streelispora catinata (Higgs) comb.nov.

3. US6E 297 II55439. Cattaraugus Fm.

4. US6E 297 II42044. Cattaraugus Fm.

Figs. 5-II. Streelispora distincta sp.nov.

5. USI2K I29 II5I323. South Wales Shale M.

6. Holotype, US6H 3I9 II9558I.
Cattaraugus Fm.

7. Detail of holotype, X I000.

8. NY96D 98 II28679. Ellicott member.

9. US6D 29I I25I5I4. Cattaraugus Fm.

I0. Proximal focus, detail of 9, X I000.

II. US6H 3I9 II8859I. Cattaraugus Fm.

PLATE 8

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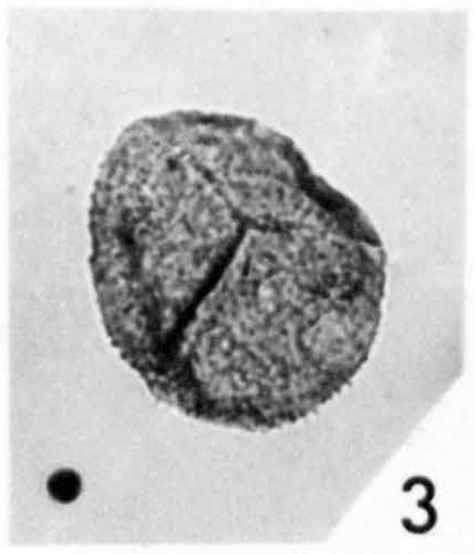

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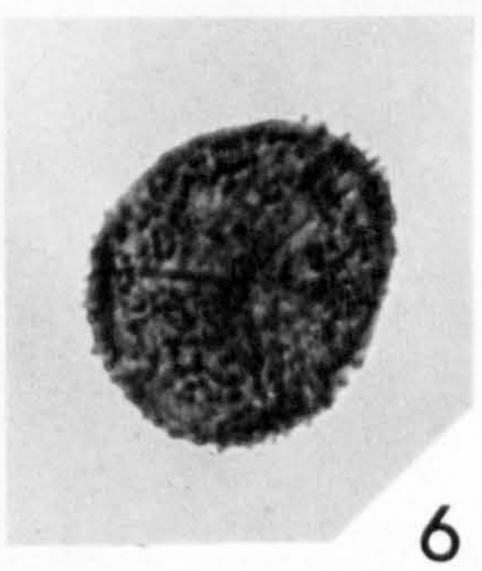

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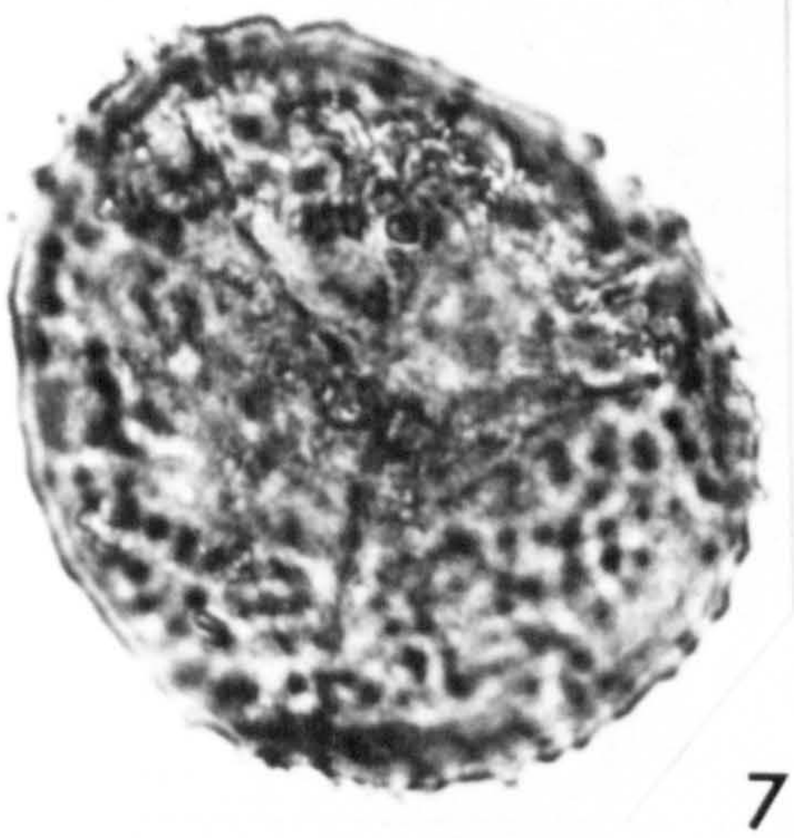

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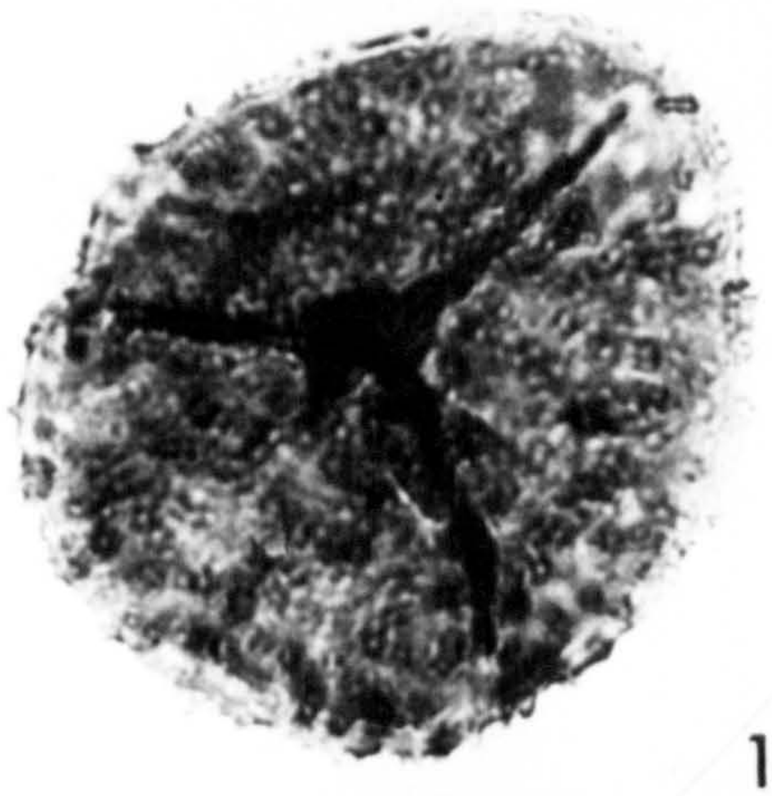

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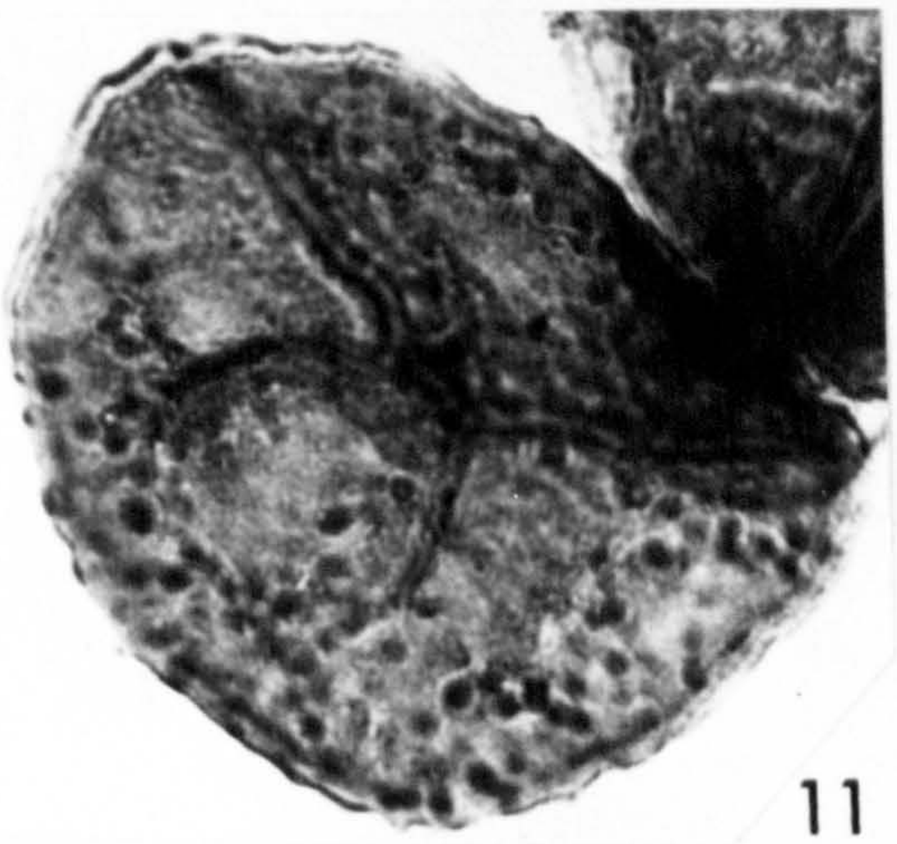

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PLATE 9

Figs. I-9. Synorisporites flexuosus (Jusch) comb. nov. Specimens showing variation in shape and prominence of equatorial thickening and nature of trilete rays.

I. US5, SEM, X 2200. Ellicott Member.

2. US5, SEM, X I050. Ellicott Member.

3. NY96A 78 II594II. Ellicott Member.

4. NY96A 39 I2I3497. Ellicott Member.

5. NY96A78 II52494. Ellicott Member.

6. Specimen with proximal wall partially collapsed, NY96C 74B I23I354. Ellicott Member.

7. US6E 297 I080442. Cattaraugus Fm.

8. NY96D 93 II69692. Ellicott Member.

9. NY96H I48 I2I9568. Ellicott Member.

Figs. I0-I2. Synorisporites richardsonii sp. nov.

I0. NY95C 37 II96063. Cattaraugus Fm.

II. Higher magnification of I0, X I000.

I2. NY96B 87 II32528. Ellicott Member.

PLATE 9

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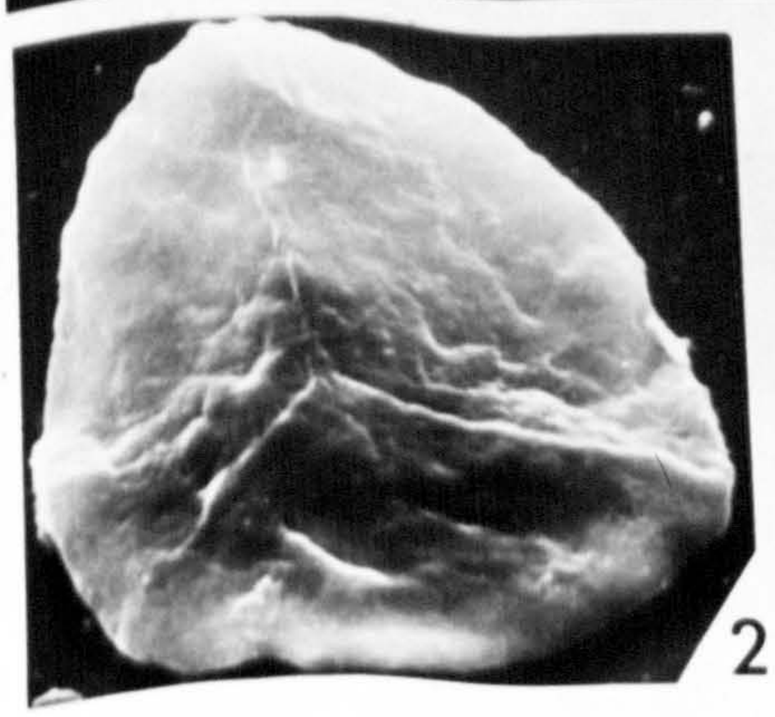

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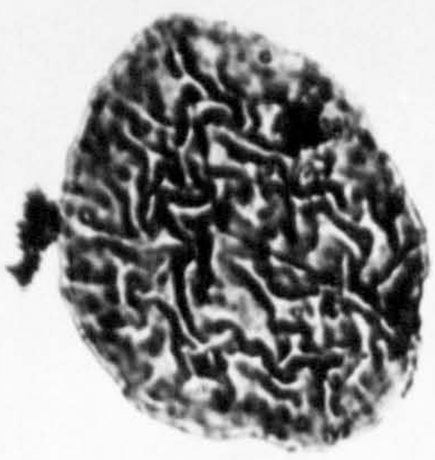

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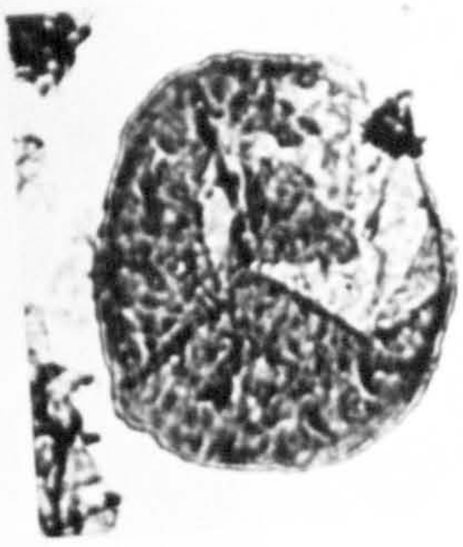

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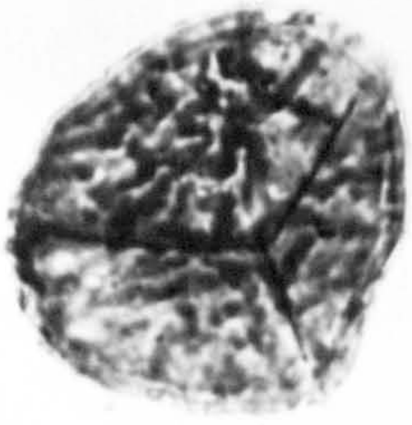

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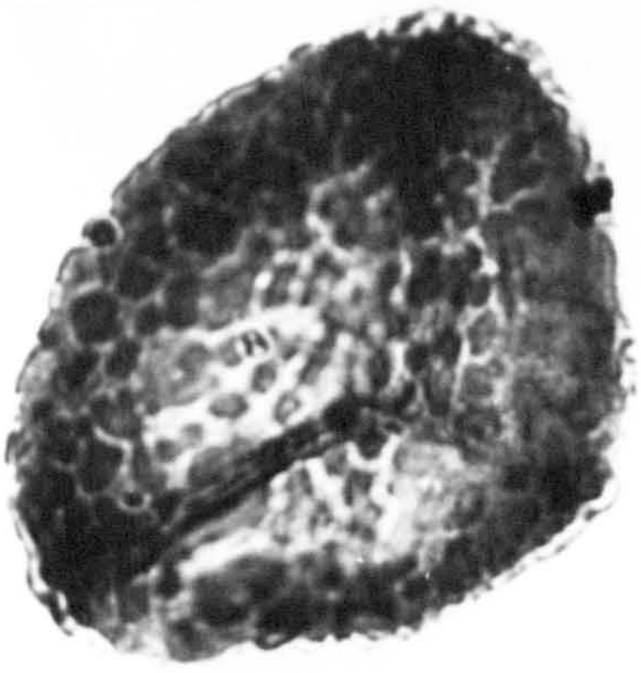

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PLATE IO

Figs. I-4. Synorisporites varuegatus sp. nov.

I. Holotype, US6D 296 I200492. Cattaraugus Fm.

2. Detail of holotype, X I000.

3. US6D 296 I2I2069. Cattaraugus Fm.

4. US6D 296 I206492. Cattaraugus Fm.

Fig. 5. Samarisporites inusitatus Allen.

USI2L I32 II2I035. South Wales Shale Member.

Figs. 6-7. Samarisporites kedoae (Riegel) comb. nov.

6. US8A 332 II424I2. Ellicott Member.

7. US8A 334 II50043. Ellicott Member.

Figs. 8-9. Samarisporites sp. cf. S. kedoae (Riegel) comb. nov.

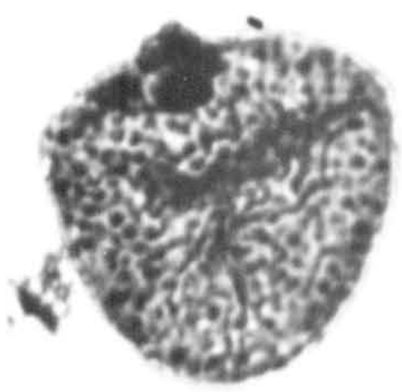
8. US8B 342 II66036. Ellicott Member.

9. Detail of 8, X I000.

Fig. IO. Spinozonotriletes sp.

US6A 266 I230468. Cattaraugus Fm.

PLATE 10



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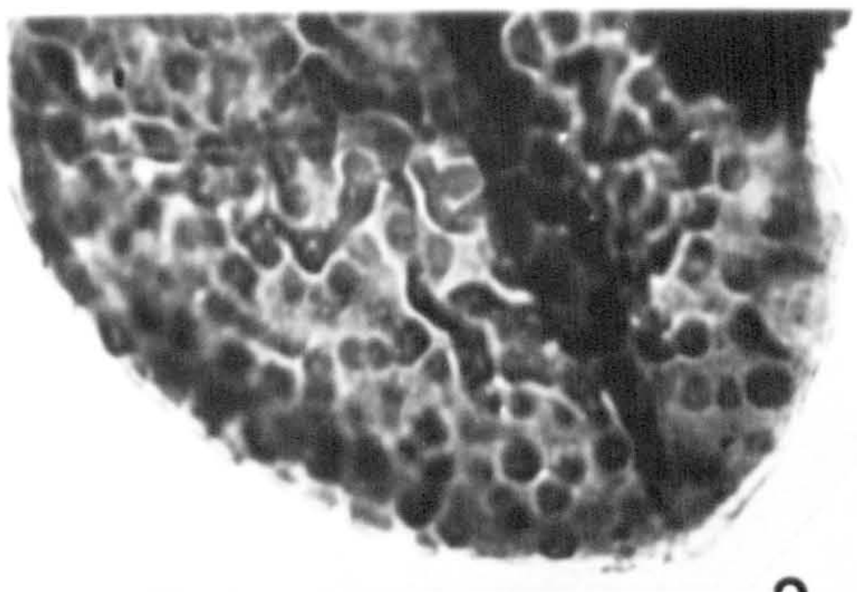

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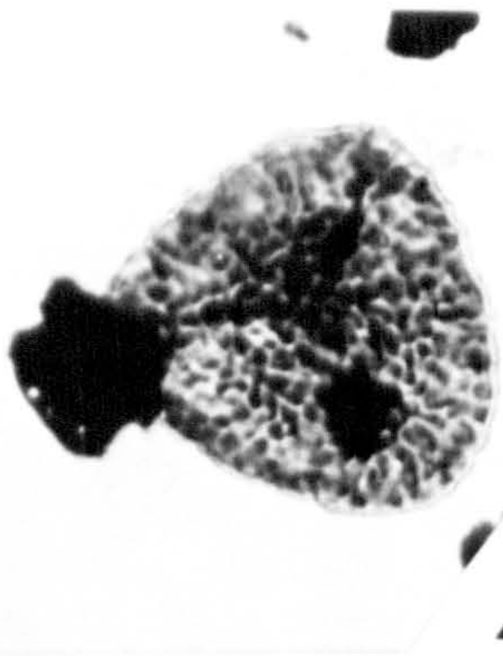

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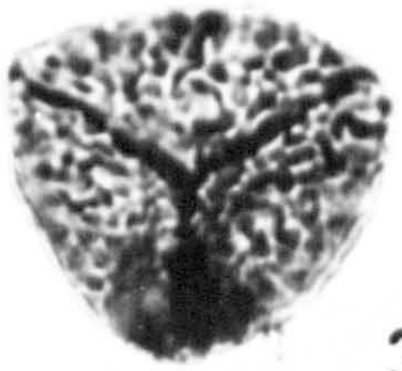

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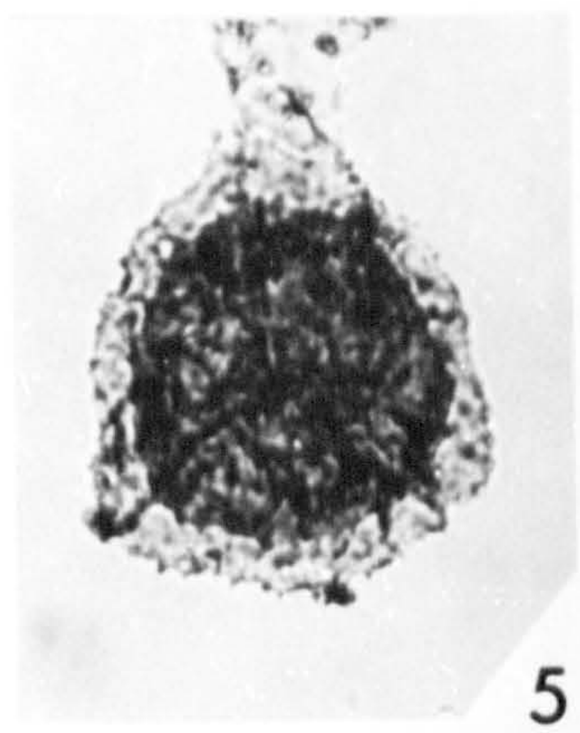

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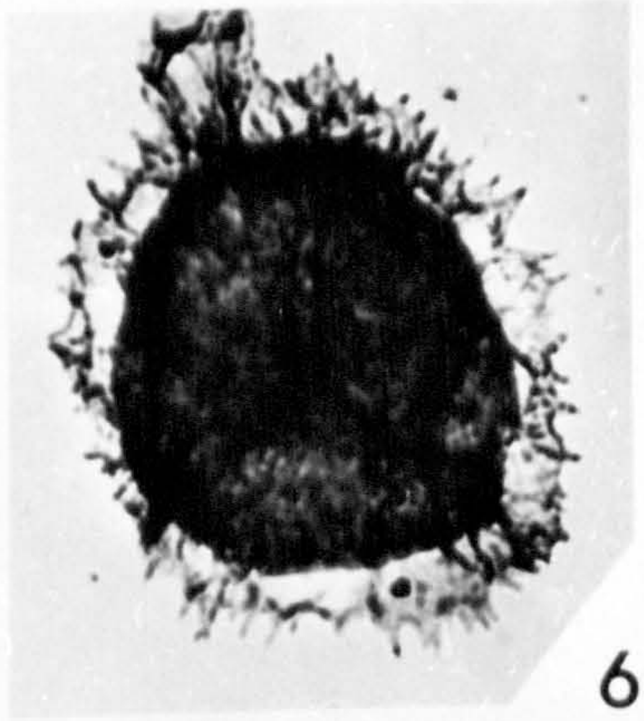

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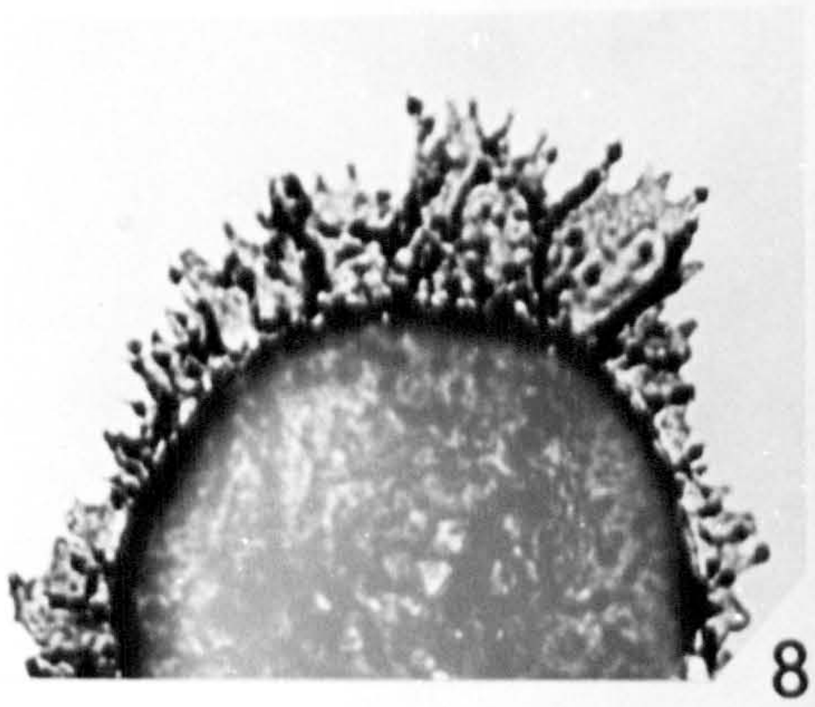

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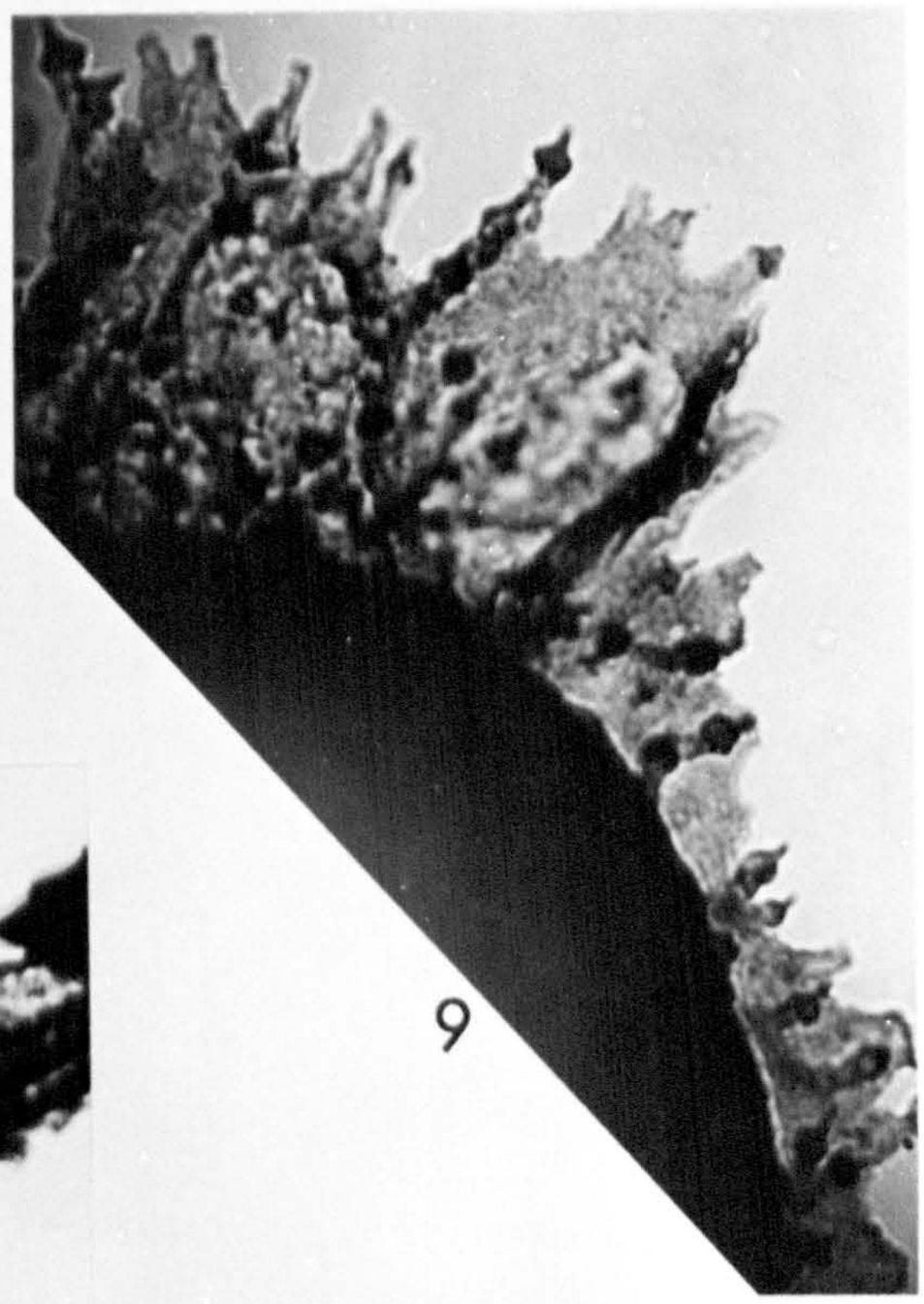

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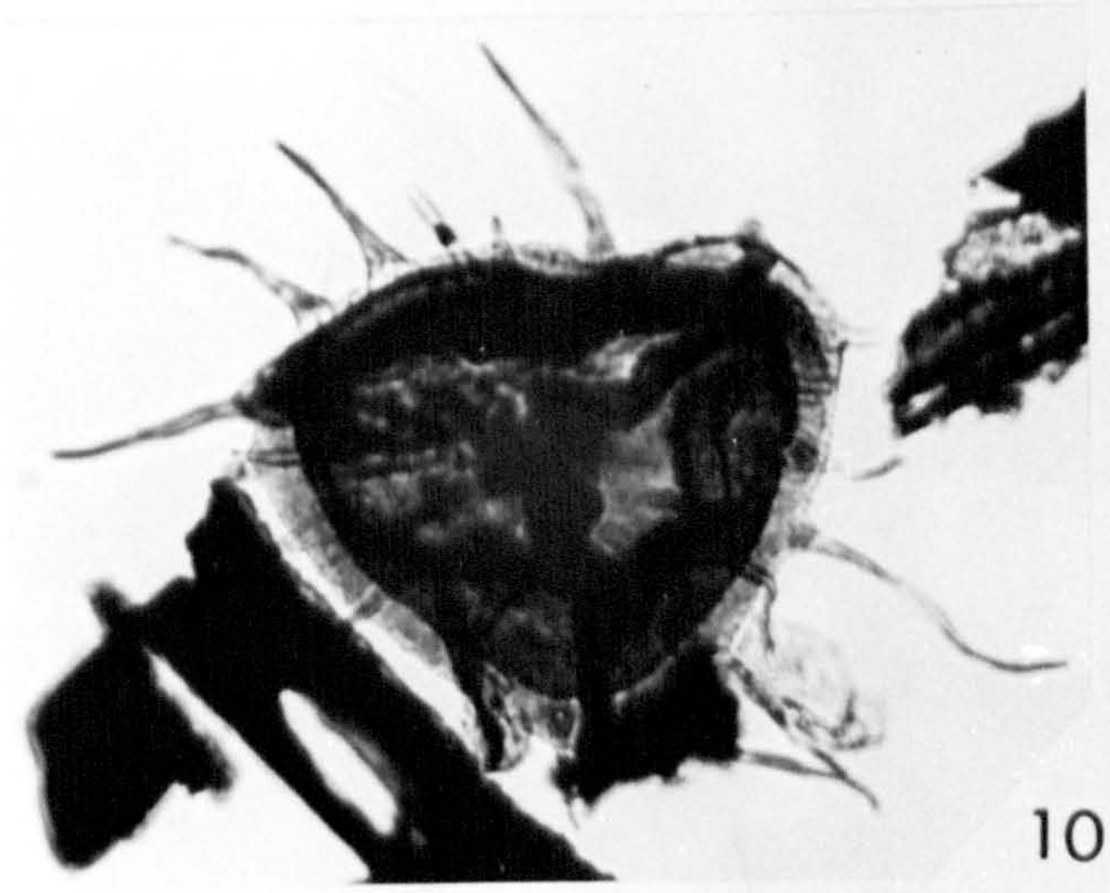

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PLATE II

Fig. I. Grandispora corunata Higgs.

US6C 286 I251549. Cattaraugus Fm.

Figs. 2-3. Grandispora echinata Hacquebard.

2. US4F 24I I254634. Dexterville Member.

3. US6C 290 I258288. Cattaraugus Fm.

Figs. 4-6. Grandispora echinula (Kedo) comb.nov.

4. NY95A Il II05618. Cattaraugus Fm.

5. US6C 286 I229272. Cattaraugus Fm.

6. Detail of 5 .

Figs. 7-9. Grandispora macroseta (Kedo) comb.nov.

7. NY95A II I2II27I. Cattaraugus Fm.

8. US6E 302 I249582. Cattaraugus Fm.

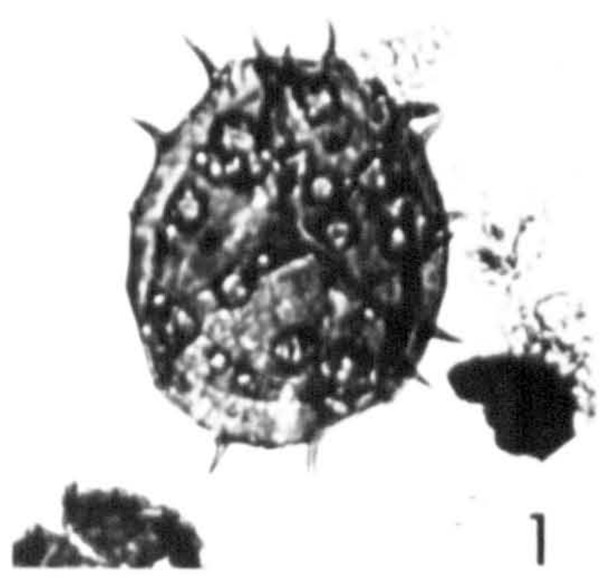
9. US4E I98 I2I2060. Dexterville Member.

Figs.IO-II. Grandispora sp. cf. G. spinosa in Massa & Moreau-Benoit.

IO. US6F 308 I260372.Cattaraugus Fm.

II. Detail of IO, X I000.

PLATE 11



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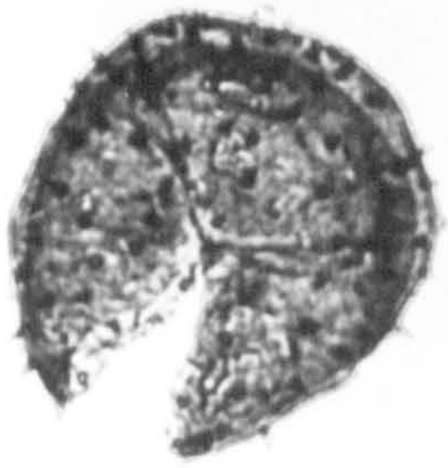

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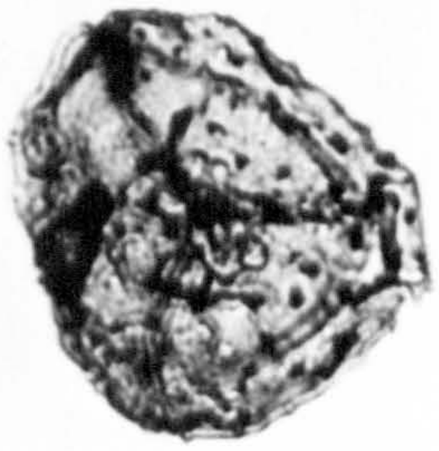

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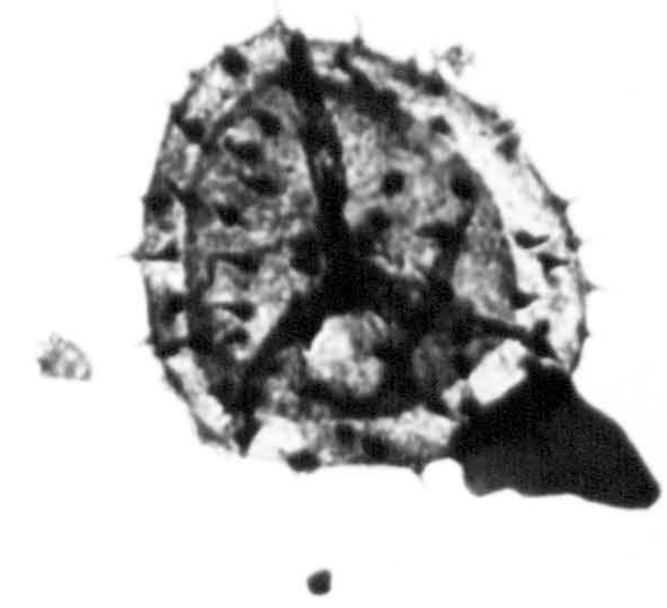

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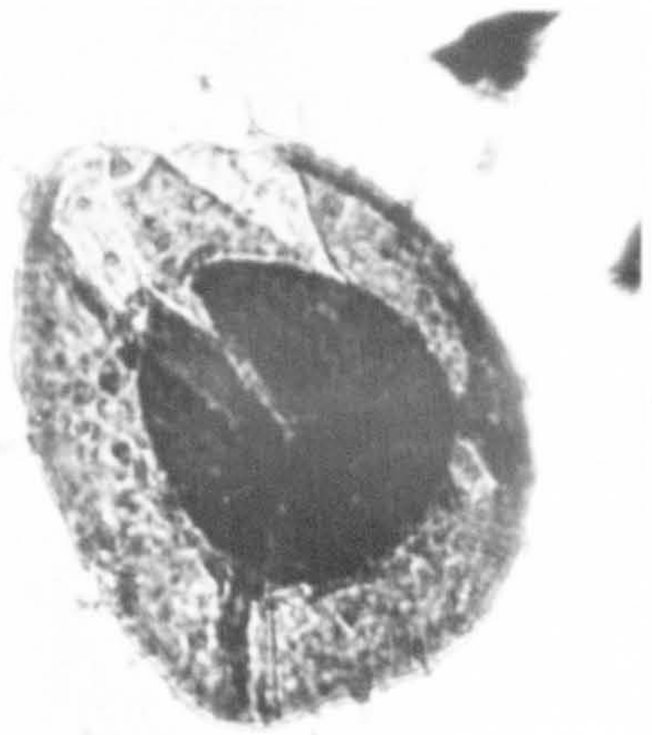

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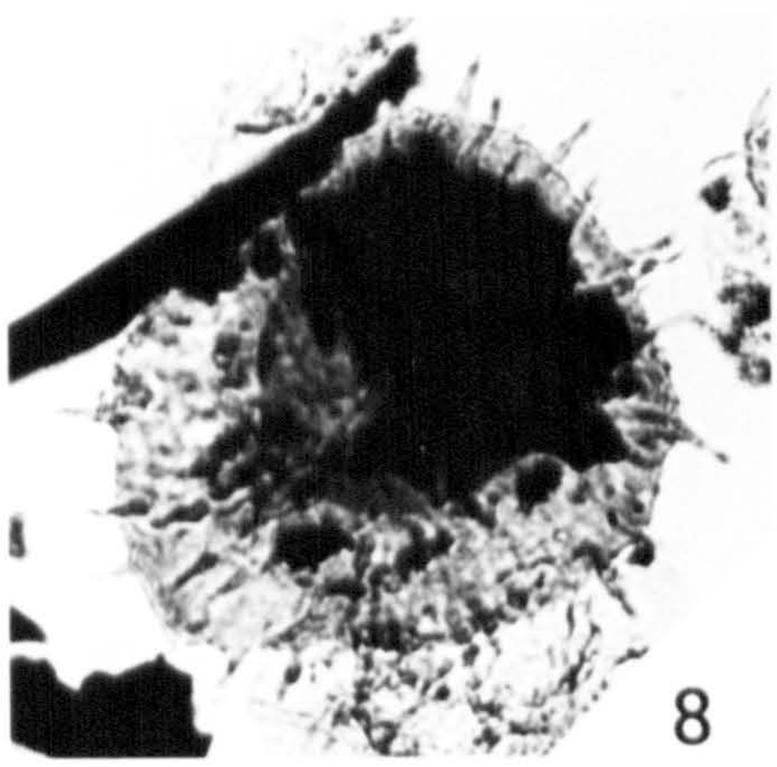

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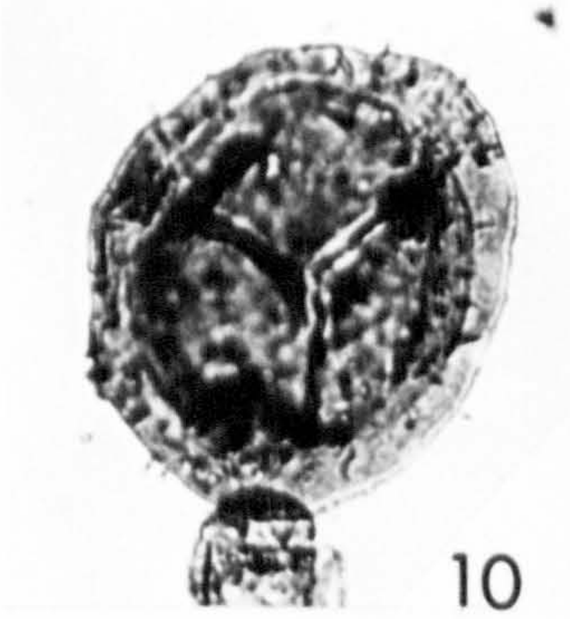

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11

PLATE I2

Figs. I-7. Calyptosporites perclarus sp.nov.

I. Holotype, US6E 299 I250339.
Cattaraugus Fm.

2. Detail of Holotype, X I000.

3. US6E 299 I242062. Cattaraugus Fm.

4. US6E 30I II90292. Cattaraugus Fm.

5. Detail of 4, X I000.

6. US6E 297 I229679. Cattaraugus Fm.

7. Part of previous specimen illustrating details of ornament, X I000.

Figs. 8-I0. Rhabdosporites parvulus Richardson.

8. US6E 297 I188532. Cattaraugus Fm.

9. US6E 297 I2I405. Cattaraugus Fm.

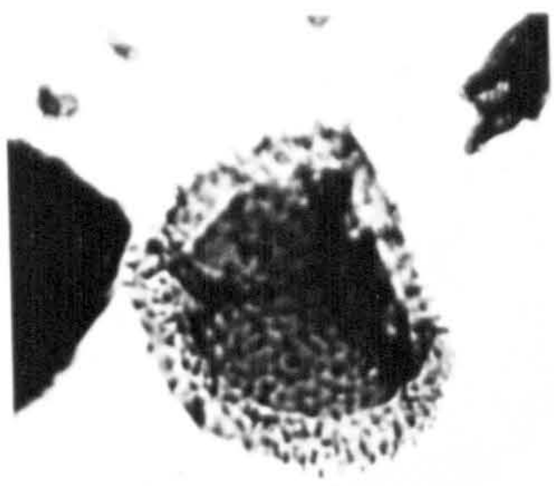
I0. US6E 297 I232 029, I000.
Cattaraugus Fm.

Figs. II-I2. Rhabdosporites langi Richardson.

II. US4A I98 I098662, X 300.
Dexterville Member.

I2. Part of previous specimen showing details of ornament, X 500.

PLATE 12



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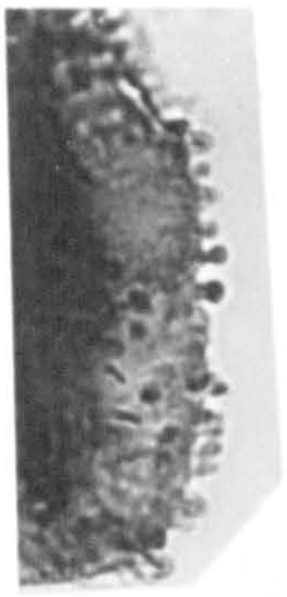

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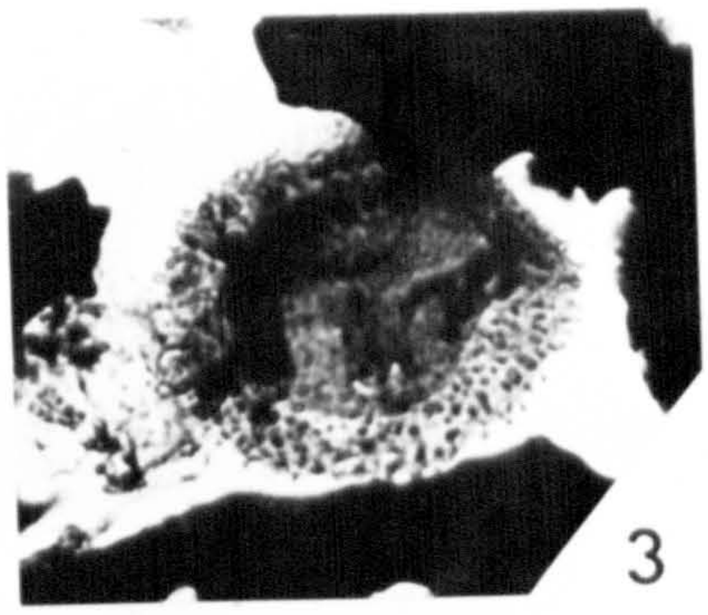

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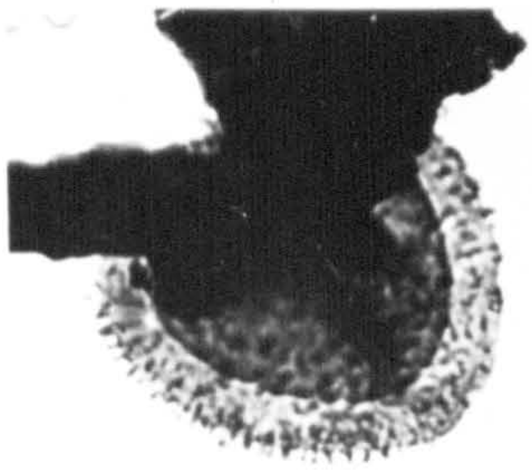

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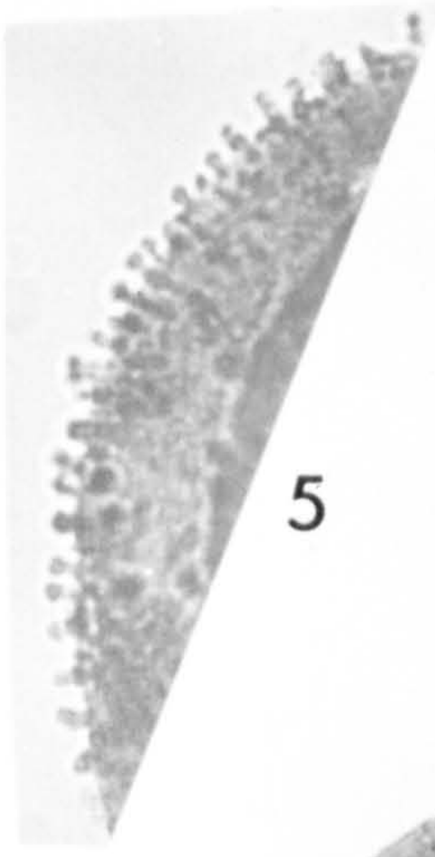

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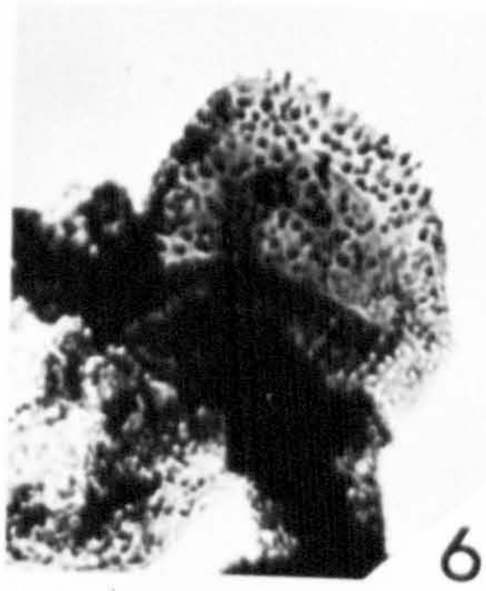

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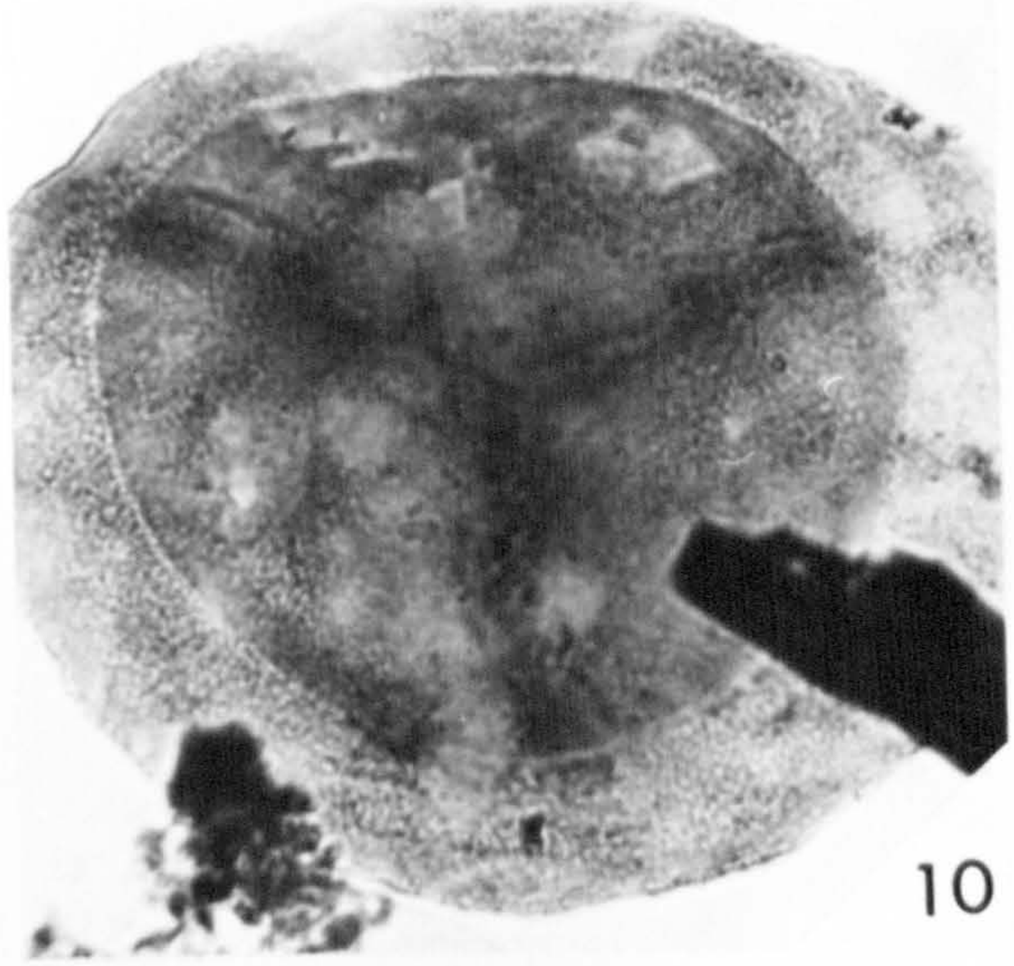

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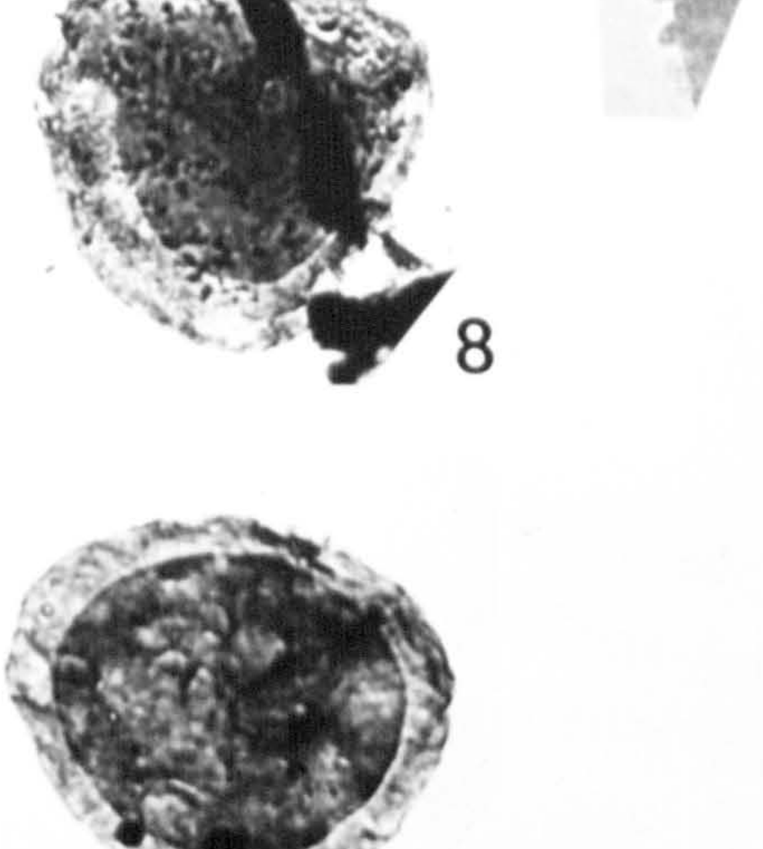

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12

PLATE I3

Figs.I-4. Retispora lepidophyta (Kedo) Playford.

I. NY96C 57 II98518. Ellicott Member.

2. A small specimen showing ill- defined reticulum, NY95C 38 II52592. Cattaraugus Fm.

3. NY96C 69 I080342. Ellicott Member.

4. NY96B 85 II90692. Ellicott Member.

Figs. 5-6. Retispora lepidophyta var. granda (Kedo) comb. nov.

5. NY96B 87 II4836I. Ellicott Member.

6. NY96B 90 II8240. Ellicott Member.

Figs. 7-9. Spelaeotriletes densatus sp. nov.

7. US6C 290 I256296. Cattaraugus Fm.

8. Holotype, US6D 296 II707I8. Cattaraugus Fm.

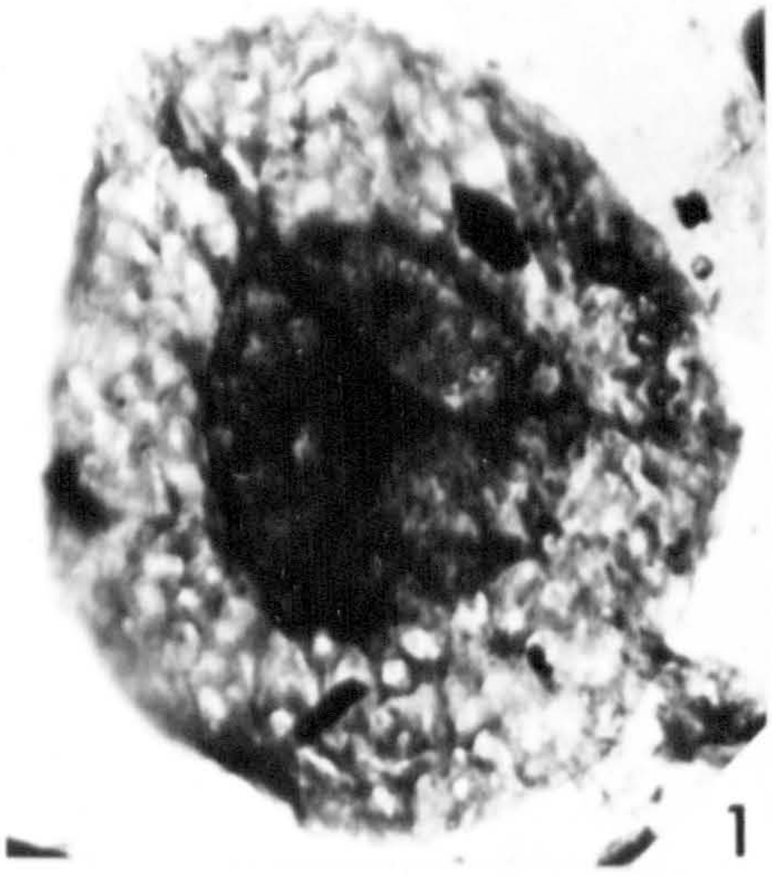
9. US6D 296 I2II339. Cattaraugus Fm.

Figs. IO-II. Spelaeotriletes microverrucosus (Kaiser) comb. nov.

IO. US5 255 II62332. Ellicott Member.

II. Detail of IO, X 1000.

PLATE 13



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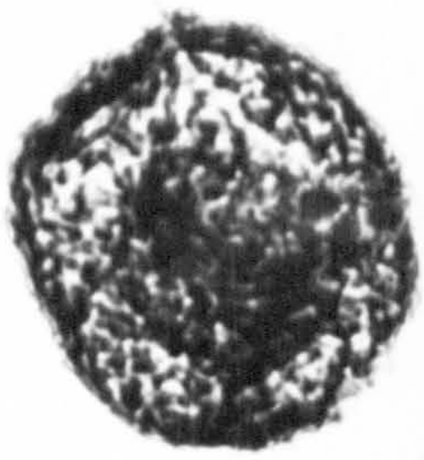

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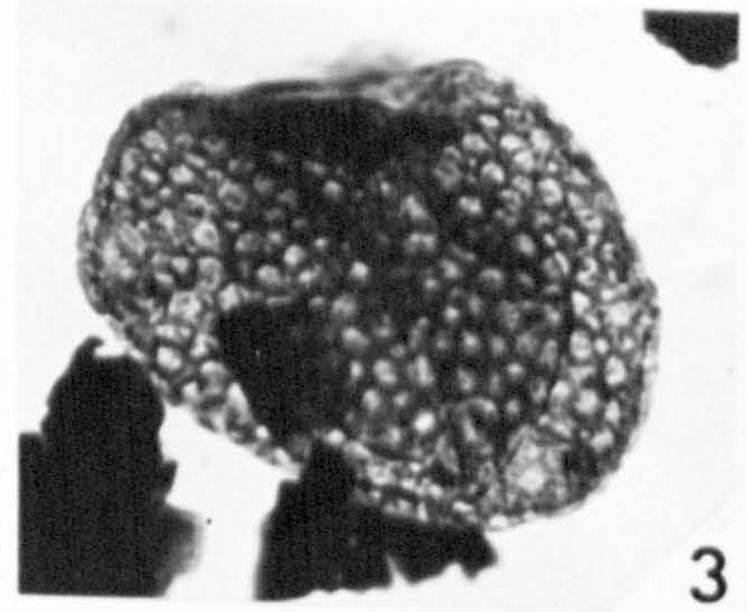

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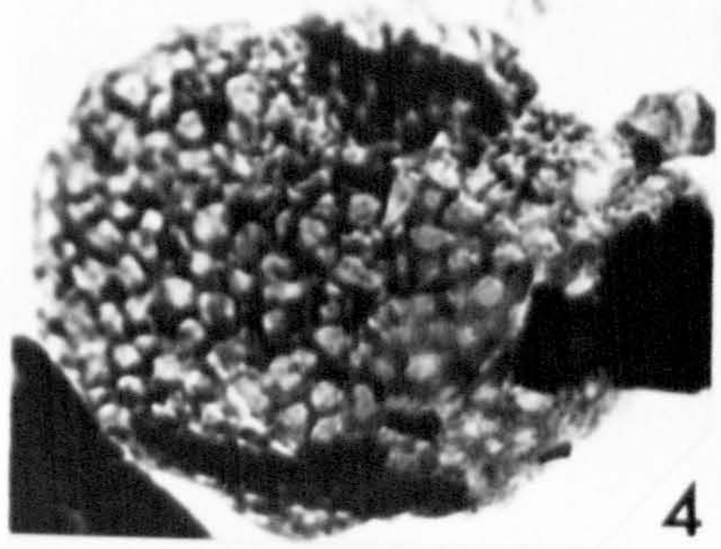

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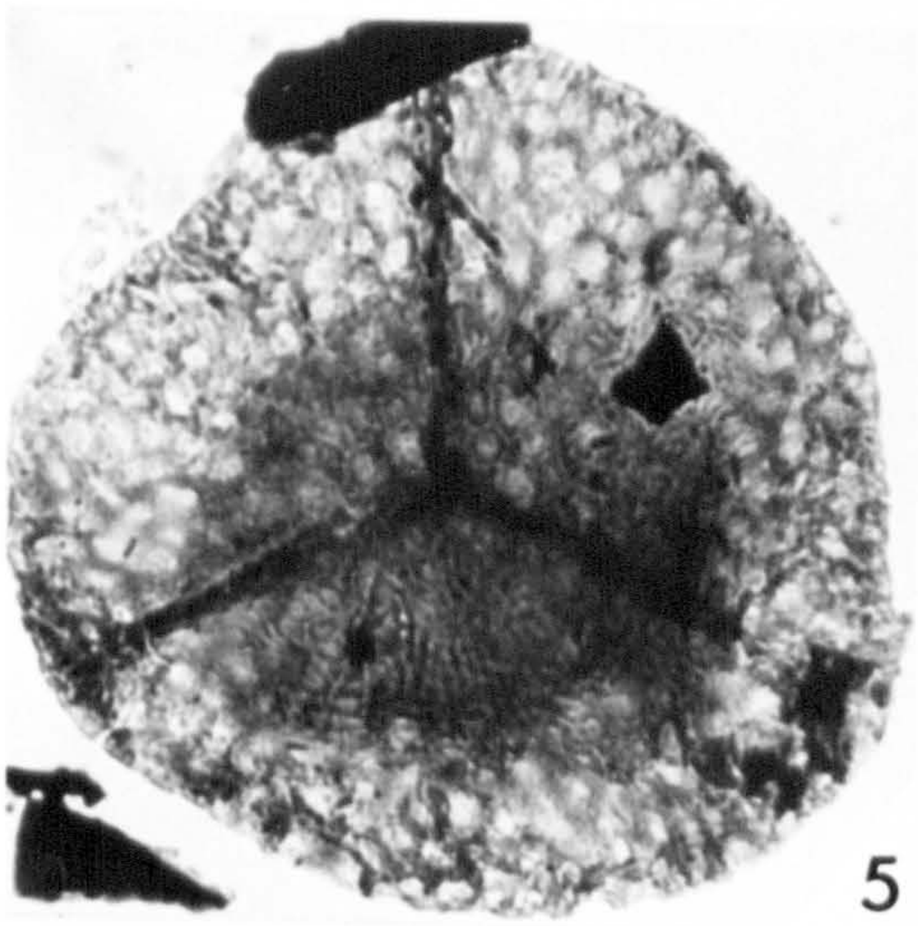

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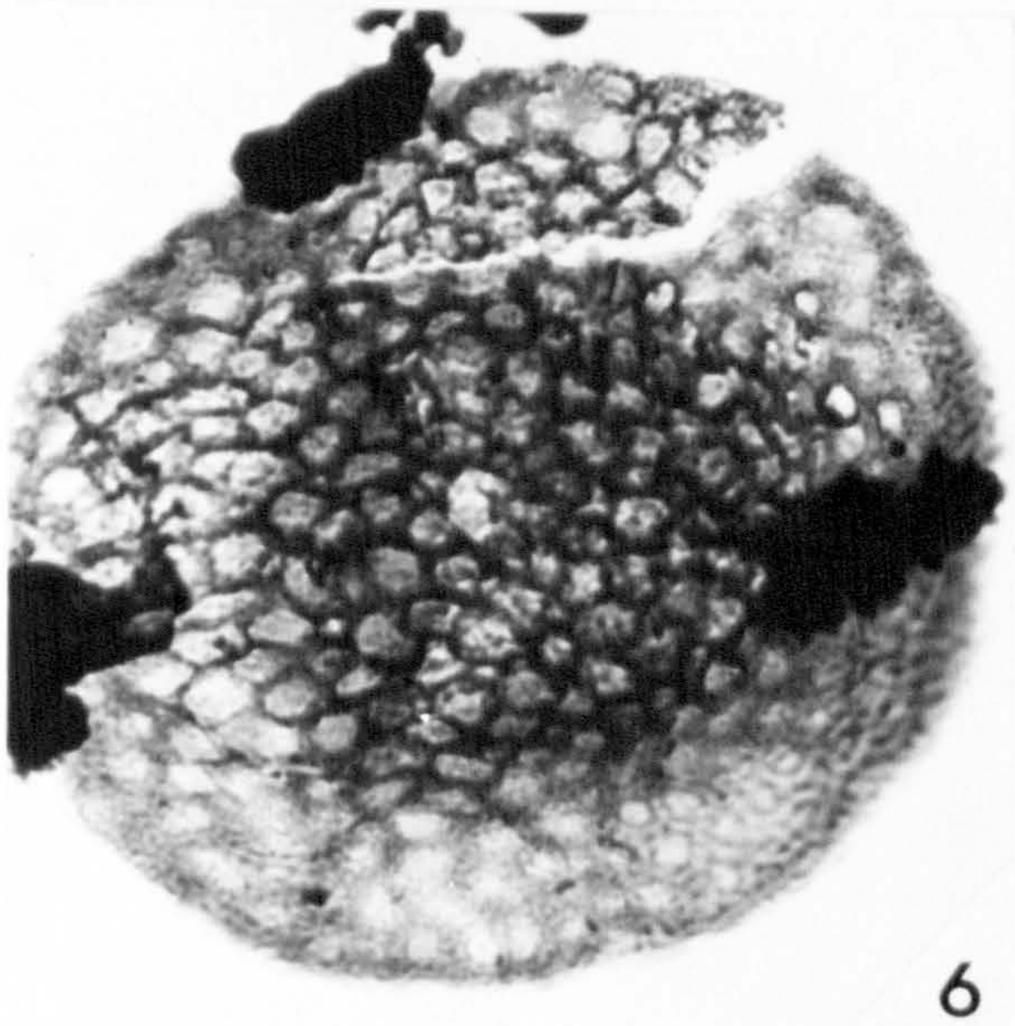

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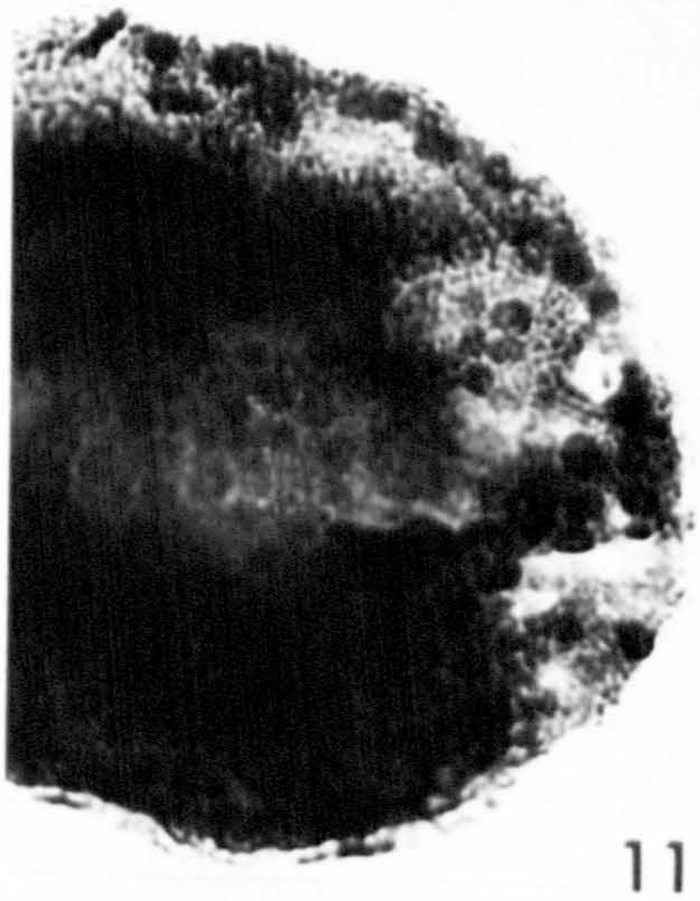


11

PLATE I4

Figs. I-3. Auroraspora callosa (Kedo) comb. nov.

I. US8B 345 II40046. Ellicott Member.

2. US4F 240 II31405. Dexterville Member.

3. US4F 240 I138708. Dexterville Member.

Figs. 4-5,7. Auroraspora commutata (Naumova) Dolby.

4. NY96C 74C I203633. Ellicott Member.

5. NY96B 87 III0606. Ellicott Member.

7. NY96B 87 II35519. Ellicott Member.

Fig. 6. Auroraspora commutata var. major (Kedo) comb. nov.

NY96E II0 I200049. Ellicott Member.

Figs. 8-9. Auroraspora micromanifesta (Hacquebard) Richardson.

8. US4B 209 Io99637. Dexterville Member.

9. USI2G 472 II8629I. Dunkirk Shale M.

Fig. I0. Auroraspora multirugata (Kedo) comb. nov.

NY96C 74 I092543. Ellicott Member.

Figs. II-I2. Auroraspora pallida (Naumova) comb. nov.

II. NY96C 74C I200474. Ellicott Member.

I2. US6E 299 I25I339. Cattaraugus Fm.

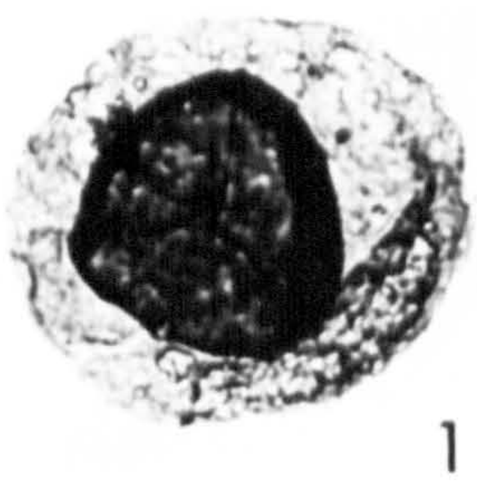
Figs. I3-I5. Auroraspora papillara (Kedo) comb. nov.

I3. NY96A 39 II34442. Ellicott Member.

I4. NY96C 74C III00522. Ellicott Member.

I5. NY96C 74C I206478. Ellicott Member.

PLATE 14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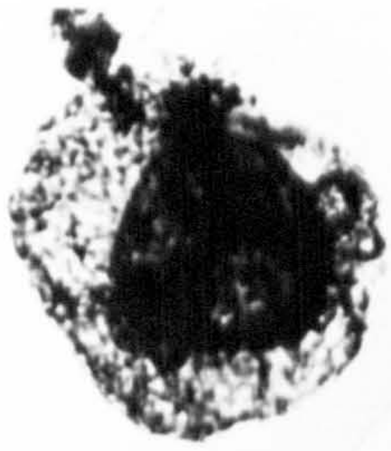
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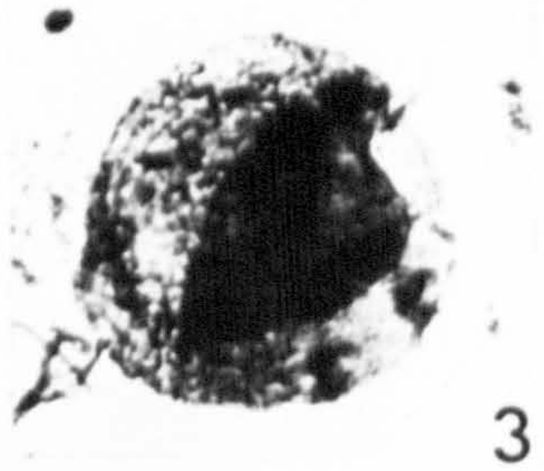
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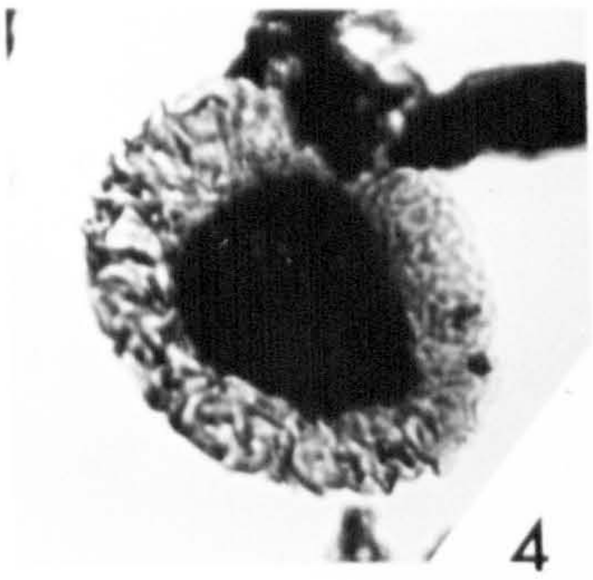
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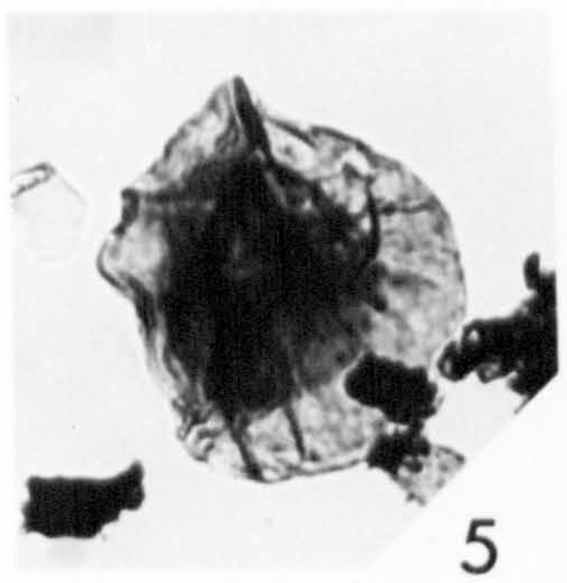
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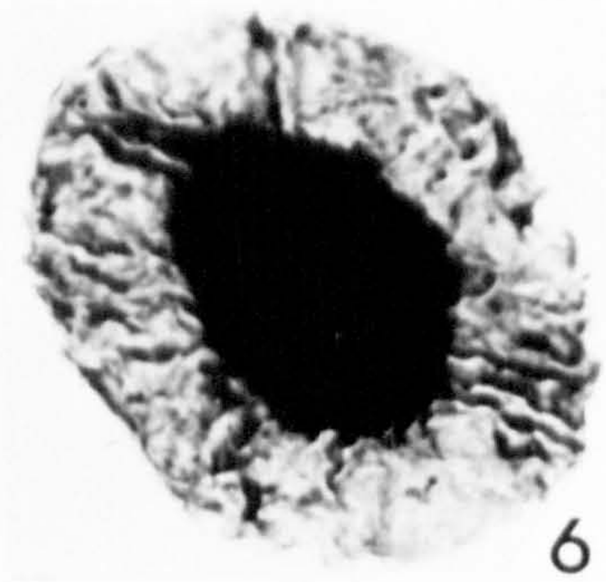
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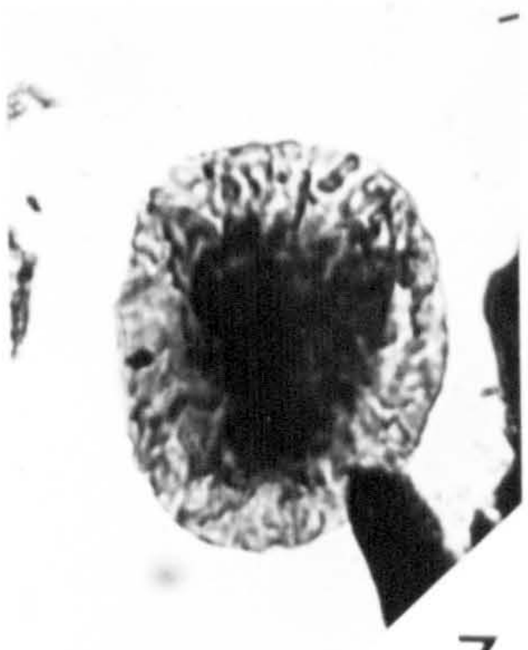
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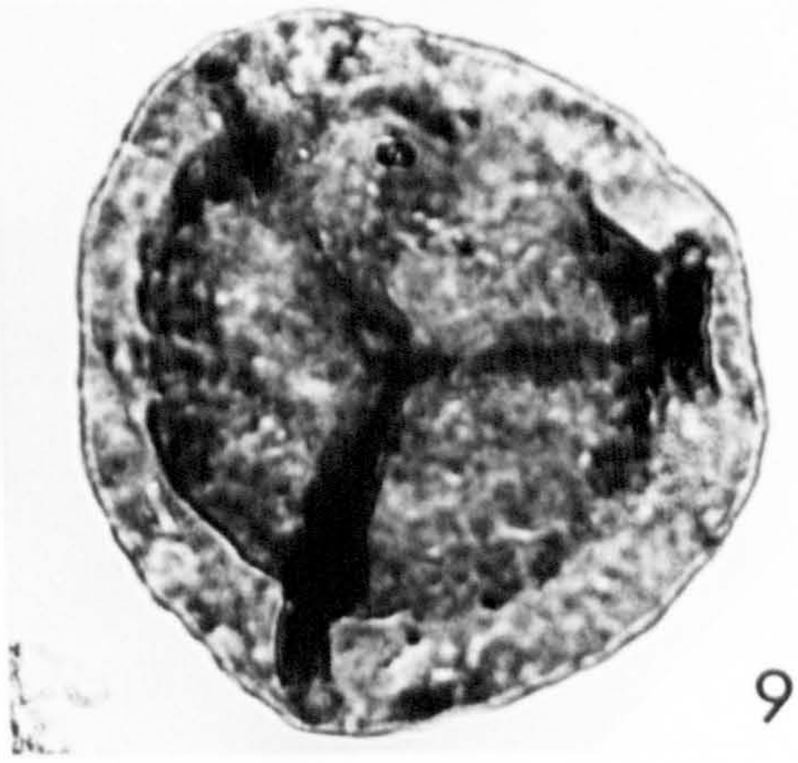
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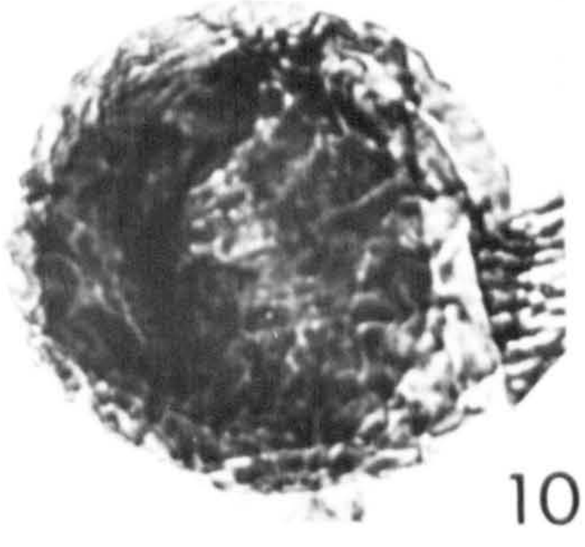
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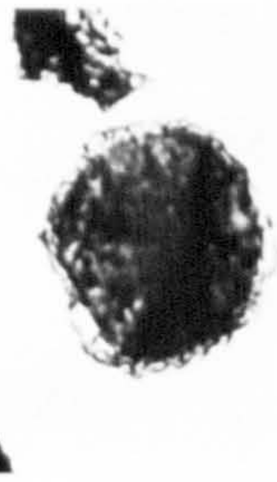
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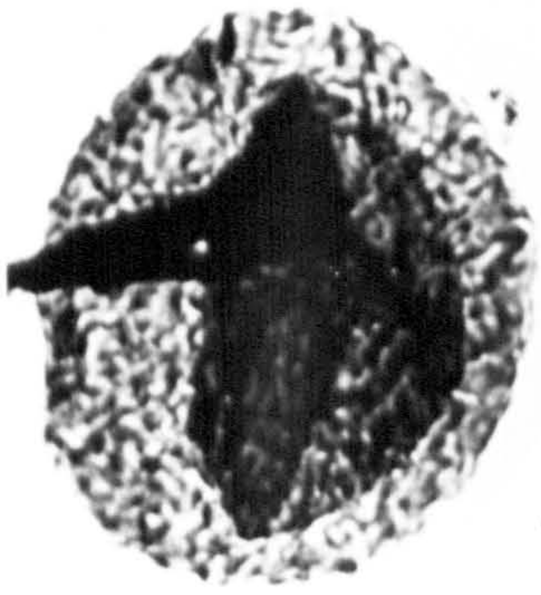
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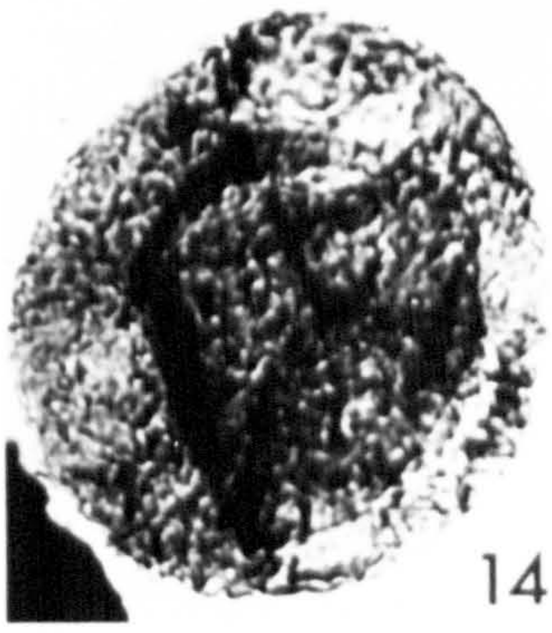
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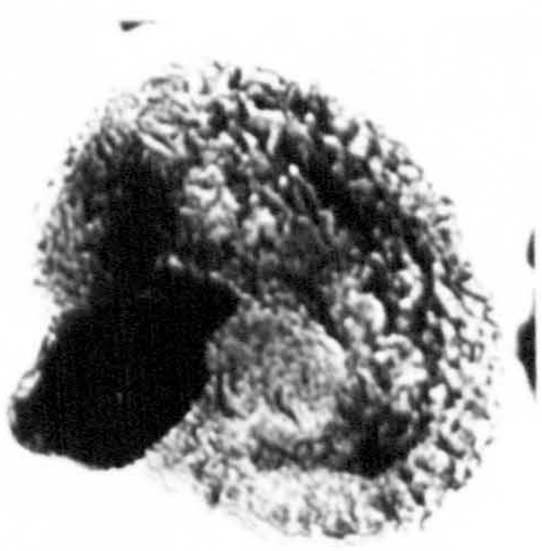
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PLATE I5

All specimens are from the Ellicott Member of Chadakoin Formation.

Figs. I-2. Auroraspora cf. papillara (Kedo) comb. nov.

I. NY96C 74C II32335.

2. NY96A 39 II53047.

Figs. 3-5. Auroraspora poljessica (Kedo) Streel.

3. NY96C 74C I222606.

4. A cluster of A. poljessica, NY96C 74 II33442.

5. Detail of 4, XI000.

Figs. 6-I0. Auroraspora prostata sp.nov.

6. Holotype, NY96C 56 I2o3553.

7. NY96H I48 II2508.

8. NY96C 74C II72027.

9. NY96C 74C II7805I.

I0. NY96C 74C III66I.

Figs. II-I2. Auroraspora prostata var. elongata var. nov.

II. Holotype, NY96C 74C II6I278.

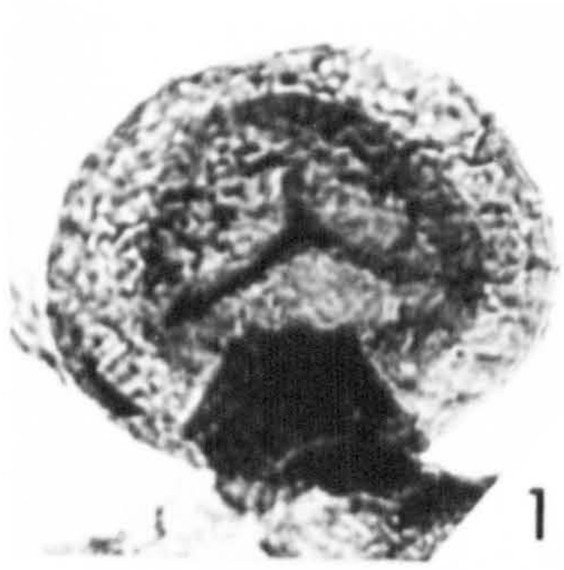
I2. NY96C 56 I20547.

Figs.I3-I4. Auroraspora prostata var. prostata var.nov.

I3. NY96C 74C III0662.

I4. Holotype, NY96C 69 II72331.

PLATE 15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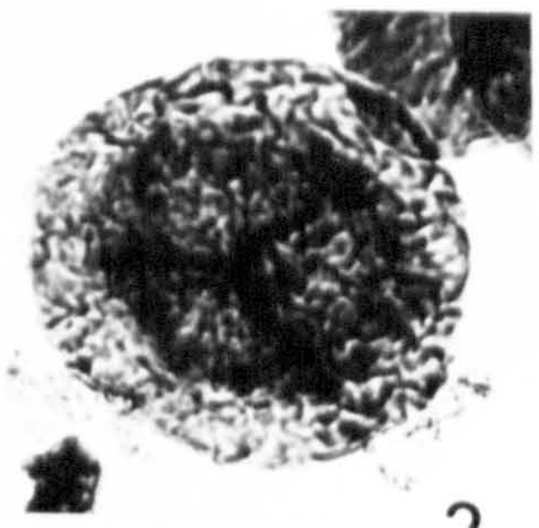
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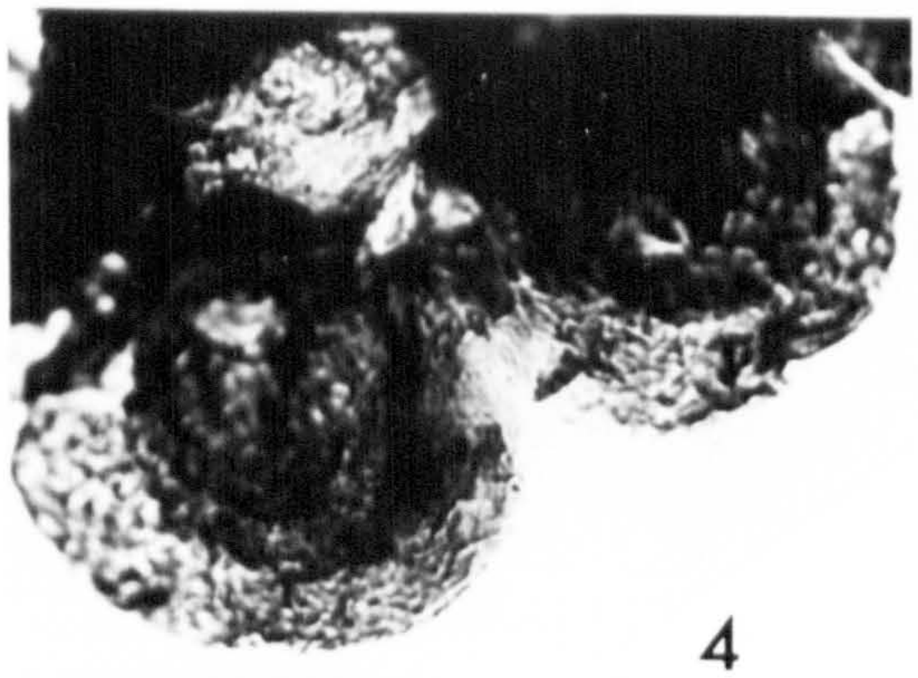
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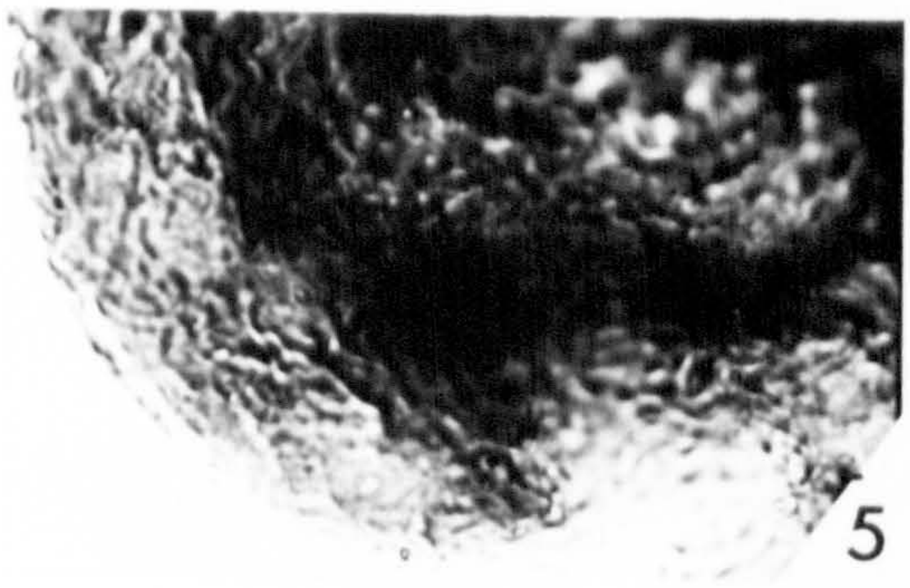
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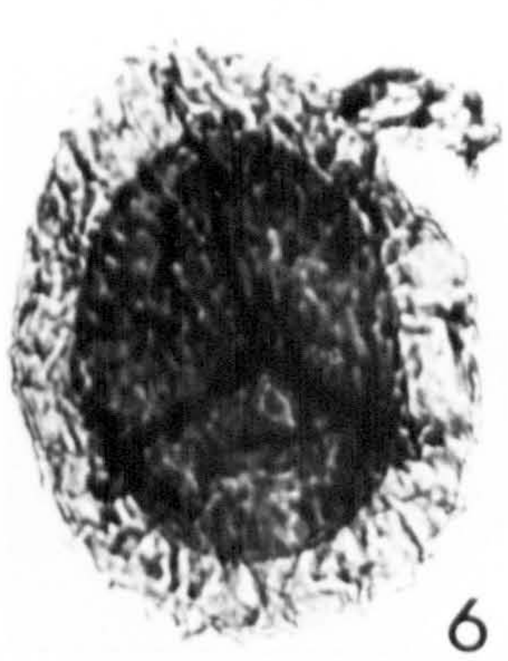
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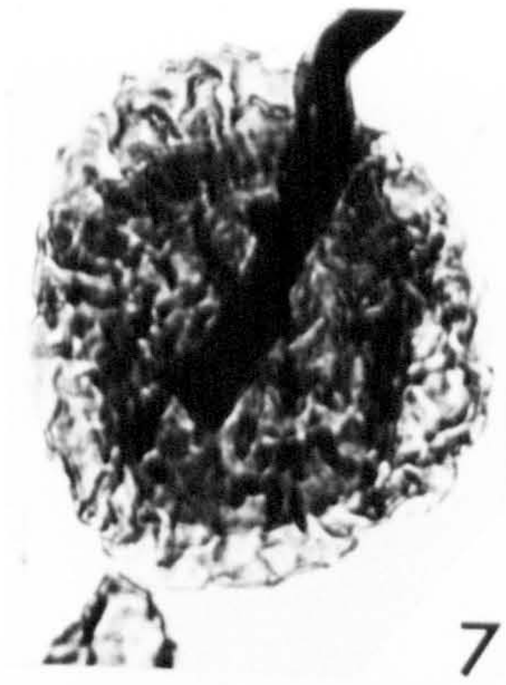
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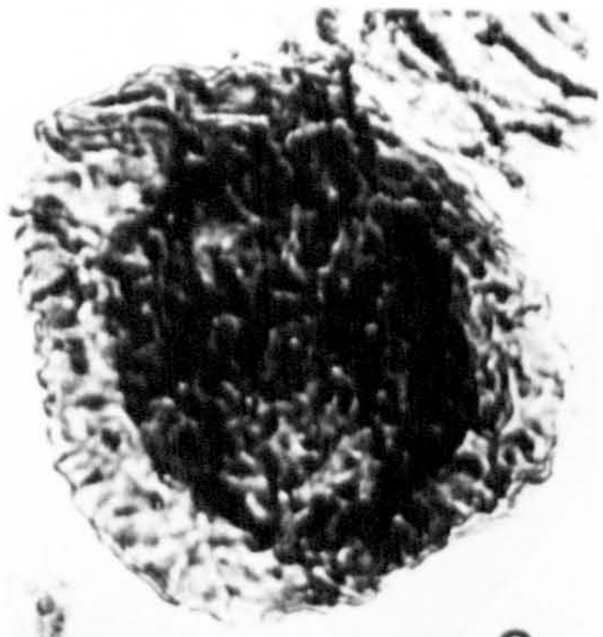
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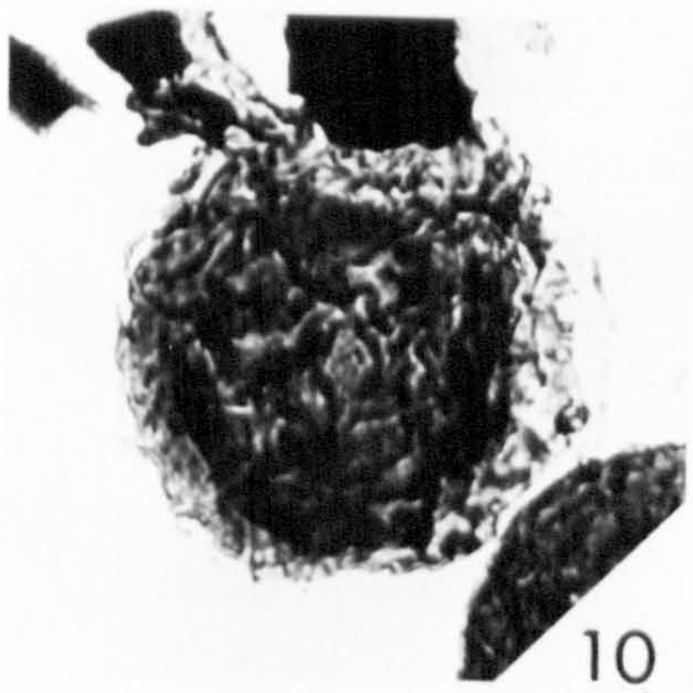
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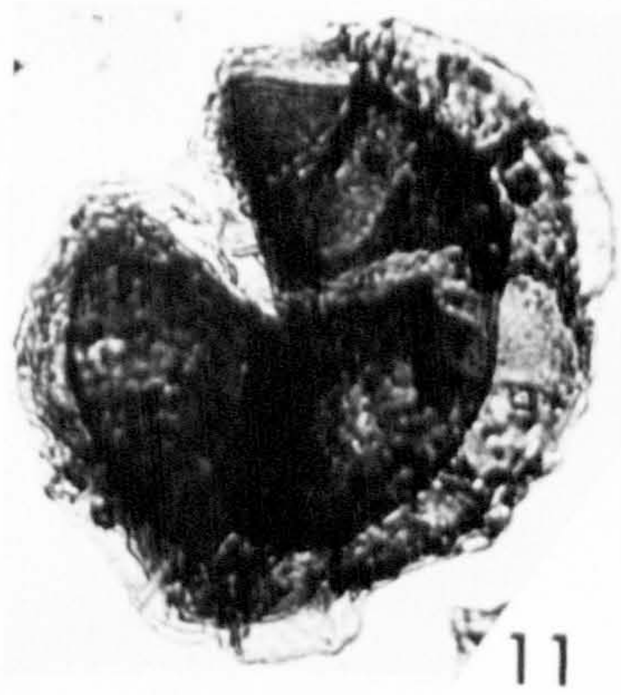
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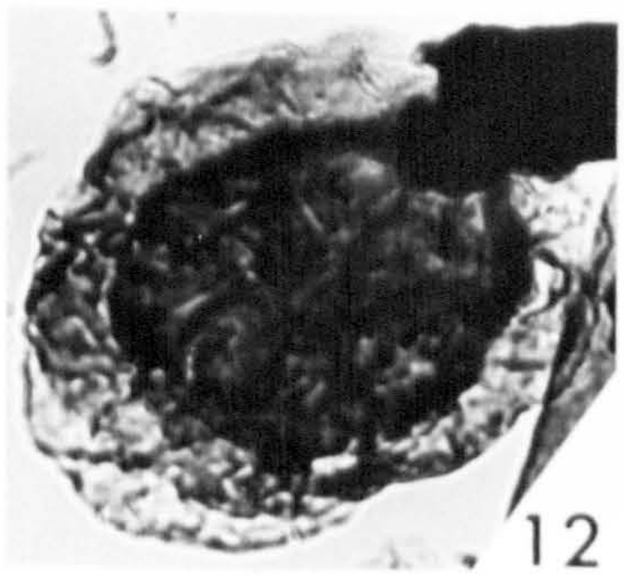
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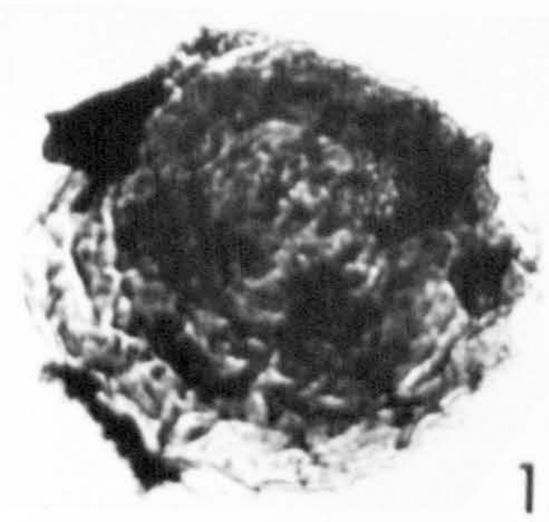
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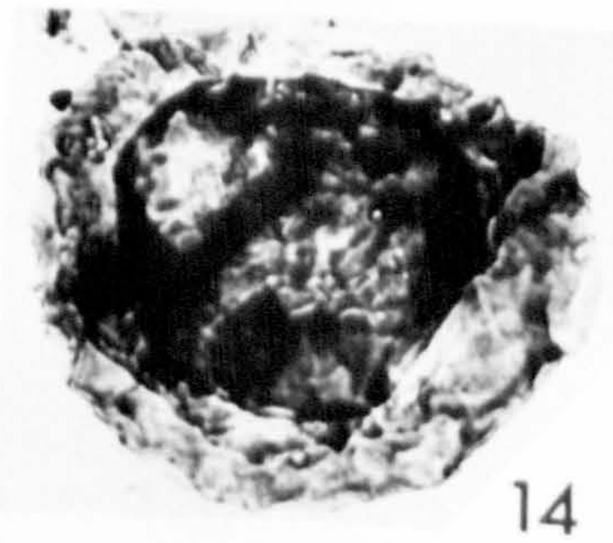
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PLATE I6

Figs. I-IO. Auroraspora pseudocrista sp.nov.

I. Holotype, US9 363 I148592. Dexterville Member.

2. Proximal focus, detail of holotype, XIOOO.

3. US4B 209 I099416. Dexterville Member.

4. Distal focus, detail of 3, XIOOO.

5. US10B 376 II770. Northeast Shale Member.

6. US4B 209 I205365. Dexterville Member.

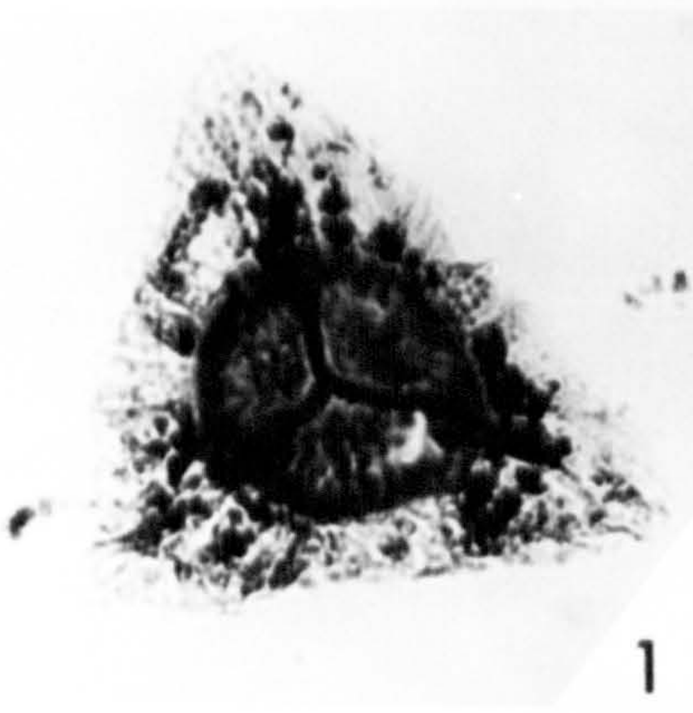
7. US10C 396 II37489. Northeast Shale Member.

8. US4E 230 II3974. Dexterville Member.

9. US4B 209 III305. Dexterville Member.

10. Part of previous specimen showing a fold, XIOOO.

PLATE 16



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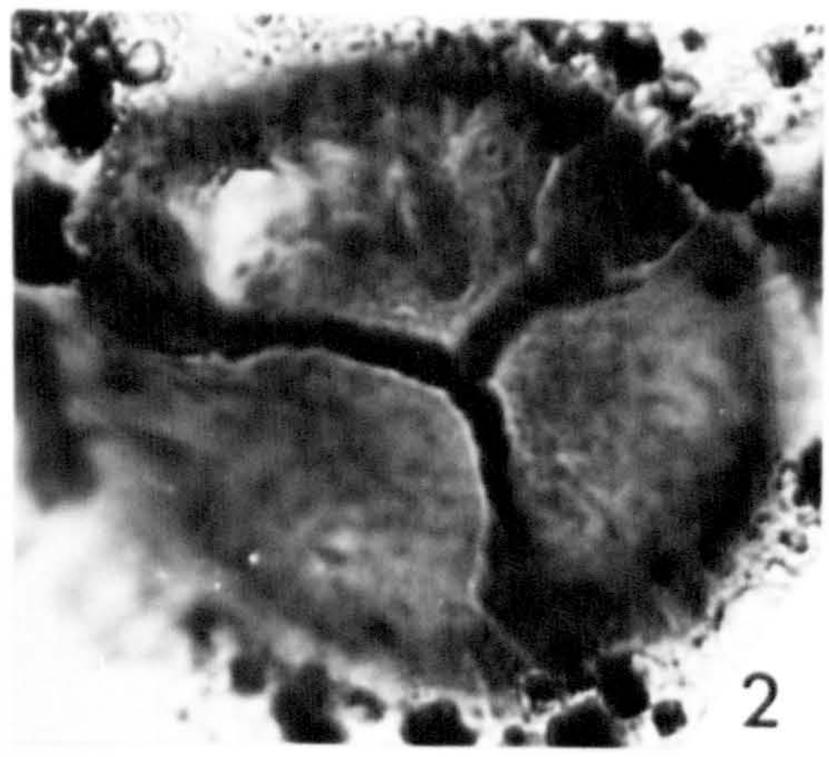

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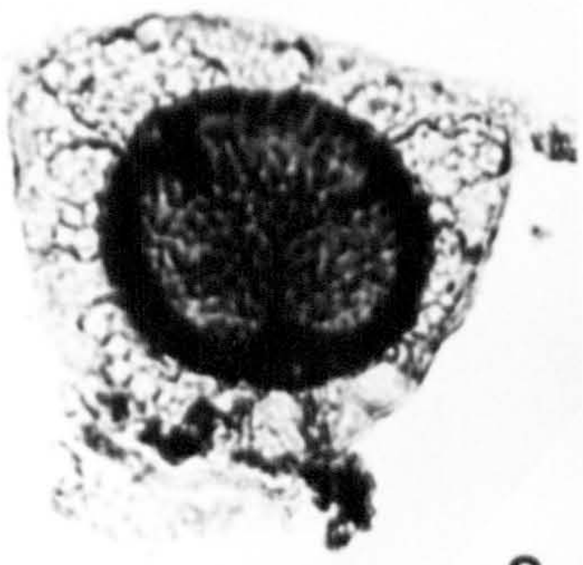

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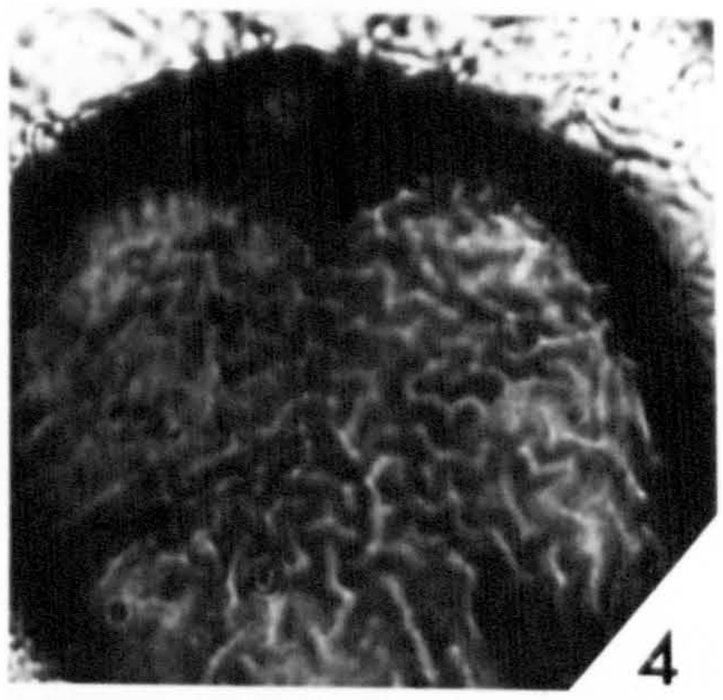

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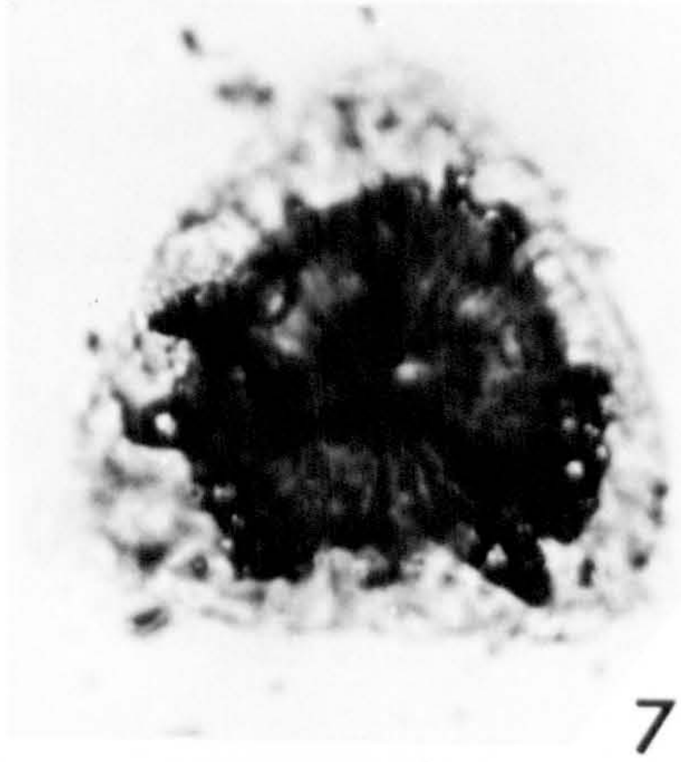

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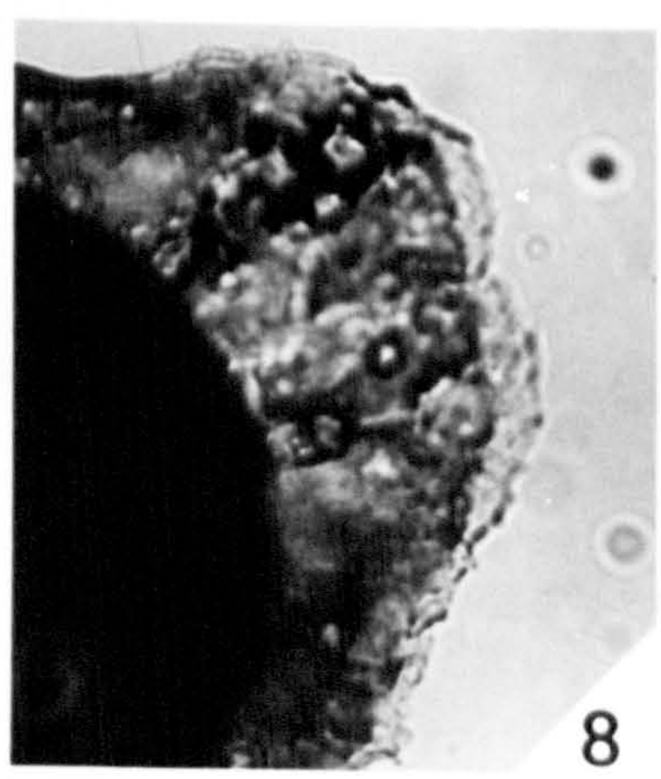

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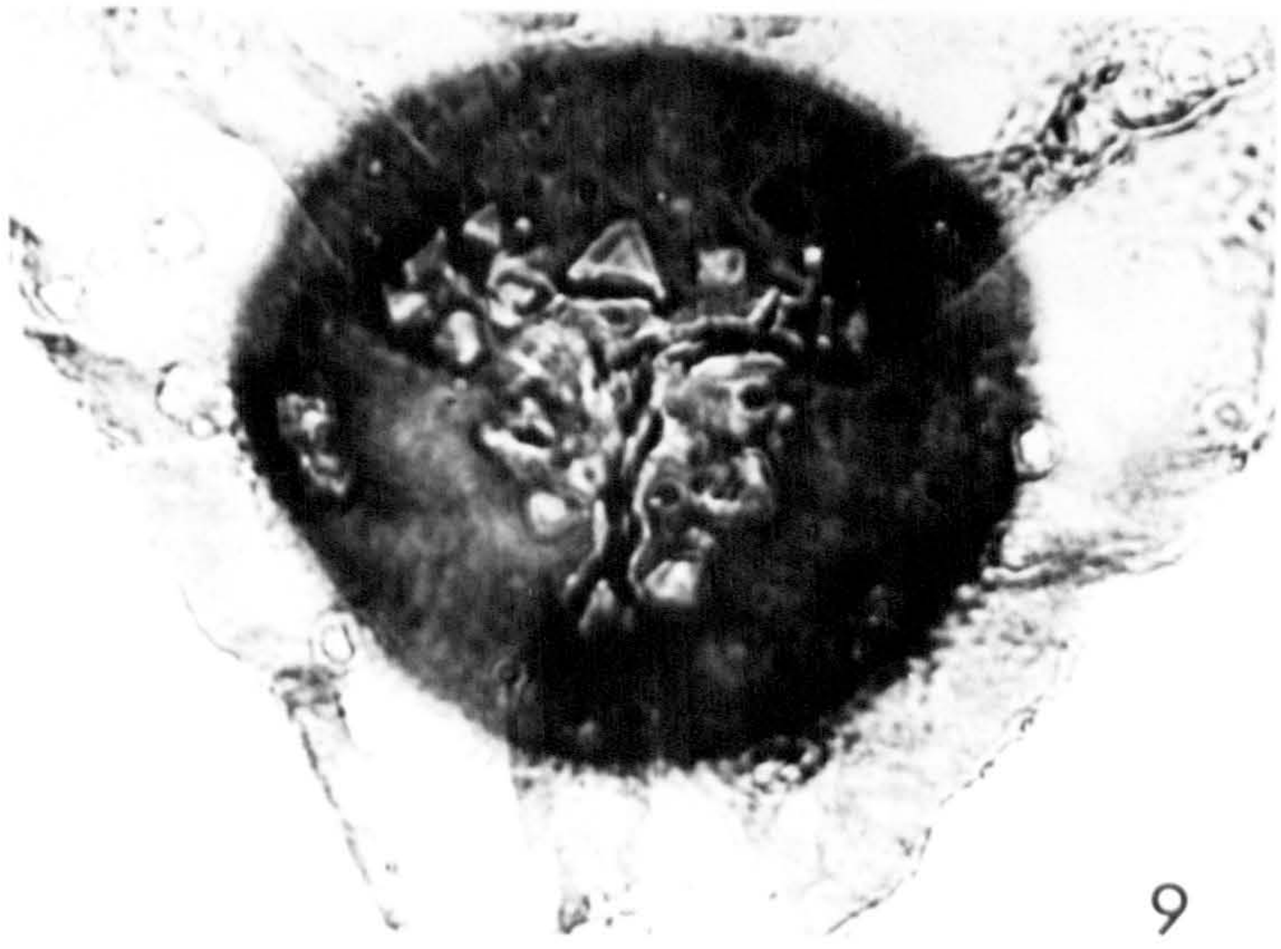

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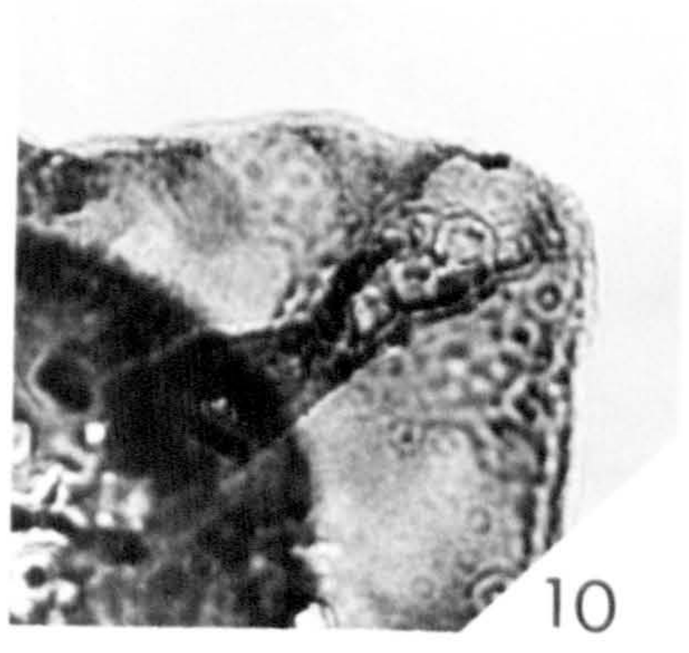

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PLATE I7

Fig. I. Auroraspora solisorta Hoffmeister, Staplin & Malloy.

US8B 34I II73573. Ellicott Member.

Figs. 2-3. Auroraspora submirabilis (Luber) comb. nov.

2. US4E 230 I2I64I6. Dexterville Member.

3. US4F 24I II4I602. Dexterville Member.

Figs. 4-5. Auroraspora torquata Higgs.

4. NY96C 74C II56046. Ellicott Member.

5. Specimen showing corroded intexine,

US6D 294 I229027. Cattaraugus Fm.

Figs. 6-8. Auroraspora varia (Naumova) comb. nov.

6. NY96C 74C II9235I. Ellicott Member.

7. NY96C 74C II55689. Ellicott Member.

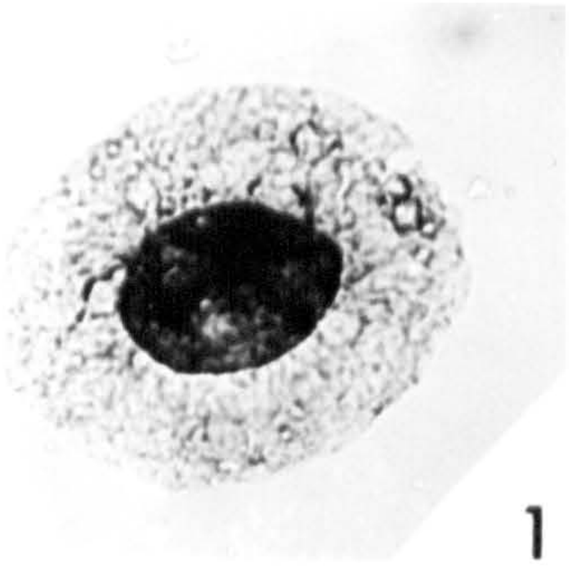
8. NY96C 74C II99724. Ellicott Member.

Figs. 9-I0. Auroraspora varia var. multifaria var. nov.

9. NY96C 74 II6I584. Ellicott Member.

I0. NY96C 74 II07552. Ellicott Member.

PLATE 17



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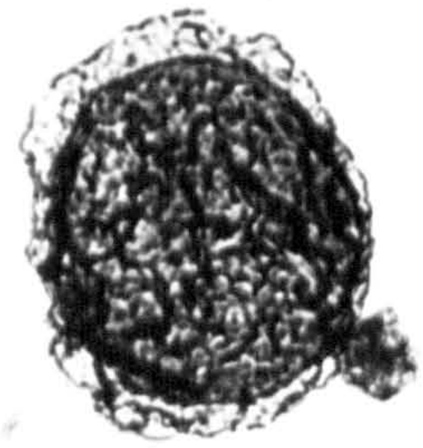

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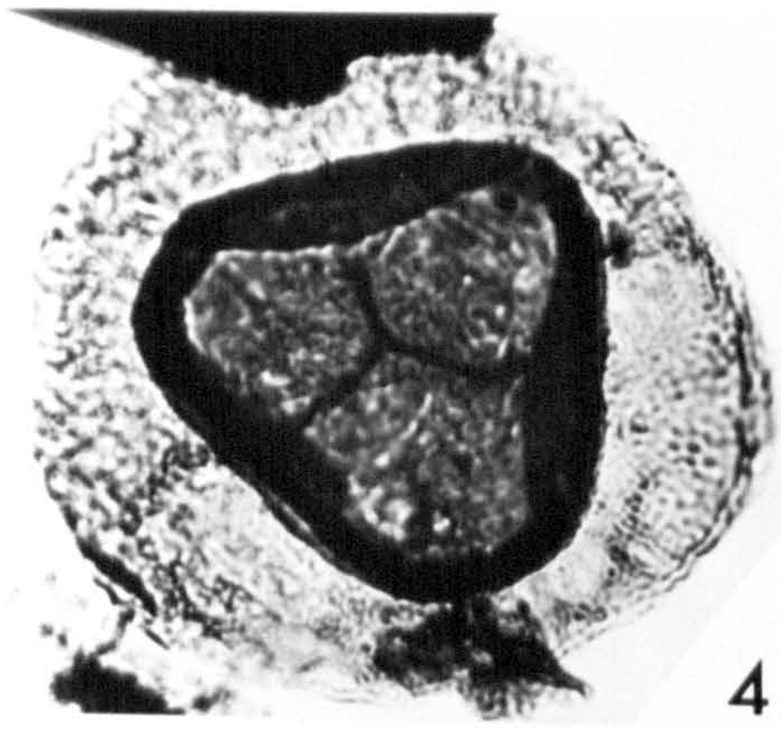

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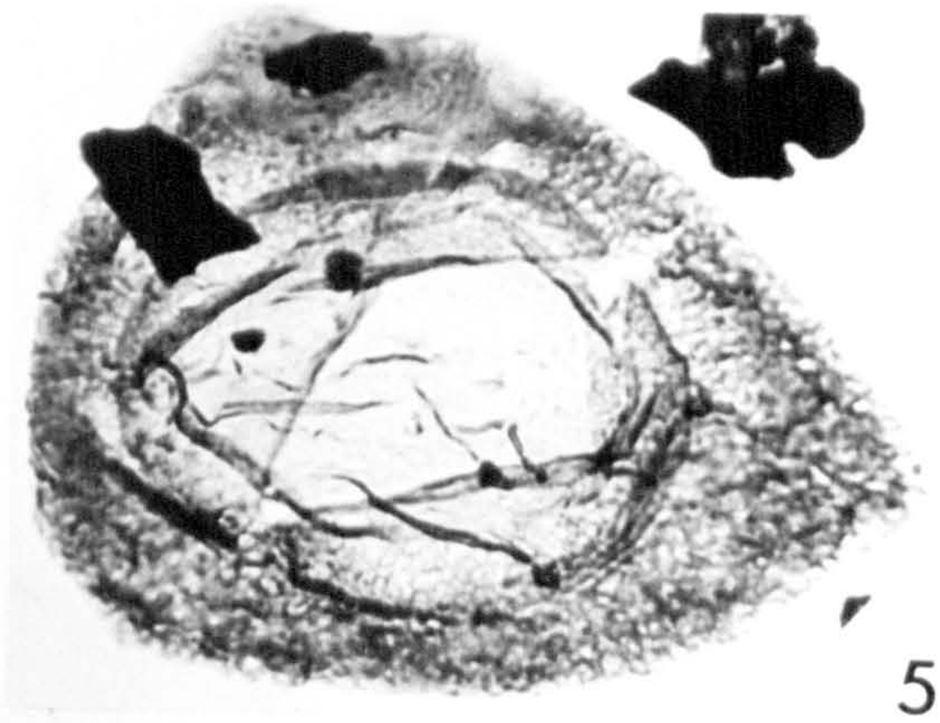

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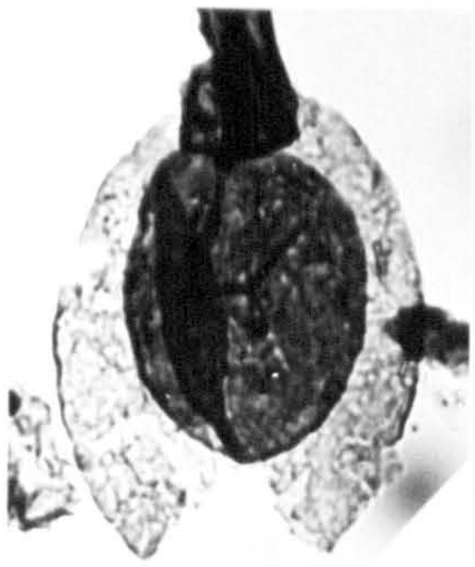

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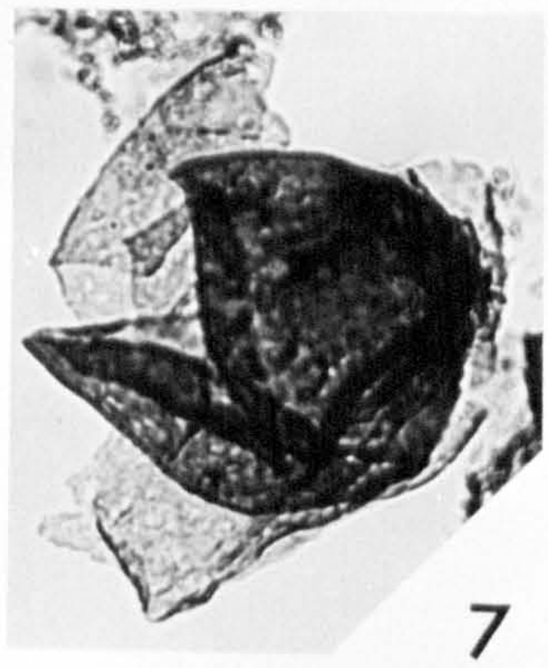

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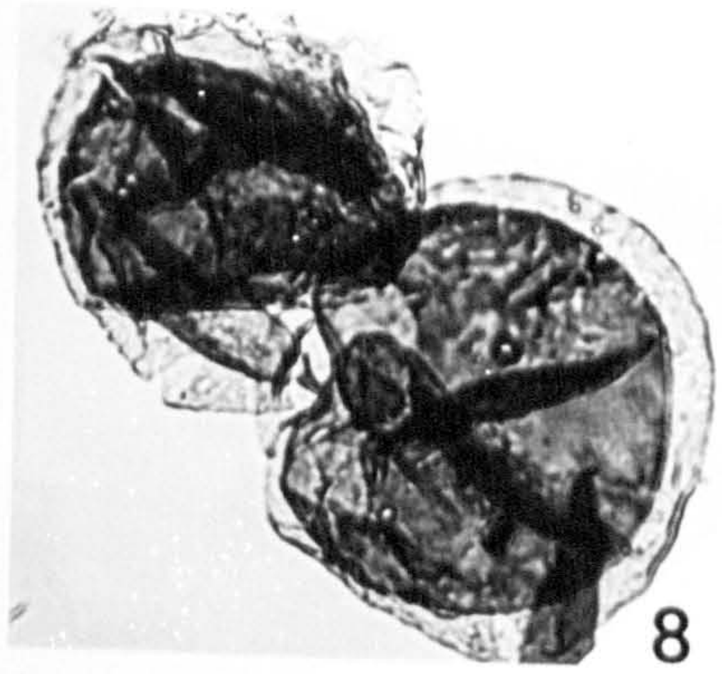

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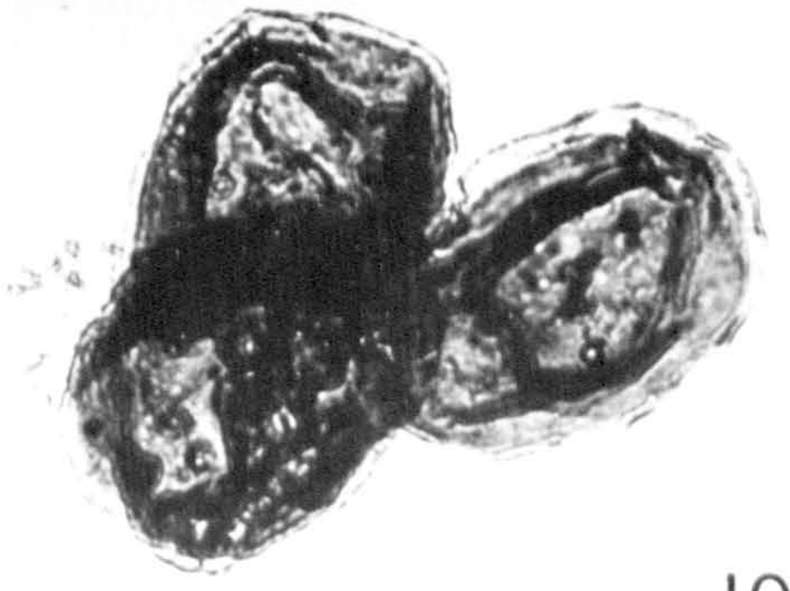

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PLATE I8

Fig. I. Auroraspora varia var. multifaria var. nov.
NY96C 56 II4I525. Ellicott Member.

Fig.2. Auroraspora versabilis (Kedo) Turnau.
NY96C 74 I1I2422. Ellicott Member.

Fig. 3. Auroraspora sp.
US8B 34I 1I89568. Ellicott Member.

Figs. 4-9. Ancyrospora acadensis sp.nov.
4. Holotype, US6E 299 I125554. Cattaraugus Fm.
5. Detail of 4, XI000.
6. Distal surface, US6E, SEM, X580.
Cattaraugus Fm.
7. Detail of 6, XII70.
8. US6E 302 I089619. Cattaraugus Fm.
9. Proximal focus, US6E 302 II9865.
Cattaraugus Fm.

Fis. IO. Ancyrospora ancyrea var. ancyrea Richardson.
USI2L I32 II3I42I. South-Wales Shale Member.

Fig. II. Ancyrospora multifurcata (Winslow) comb.nov.
US6E 30I II64558. Cattaraugus Fm.

PLATE 18

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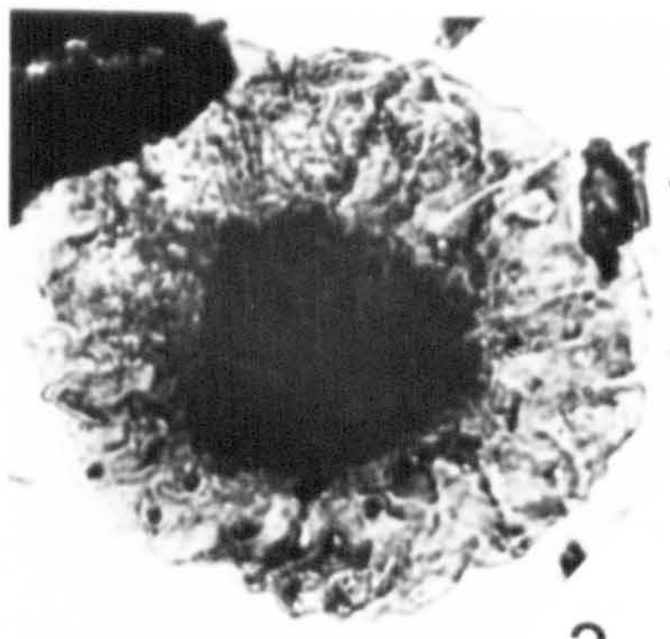

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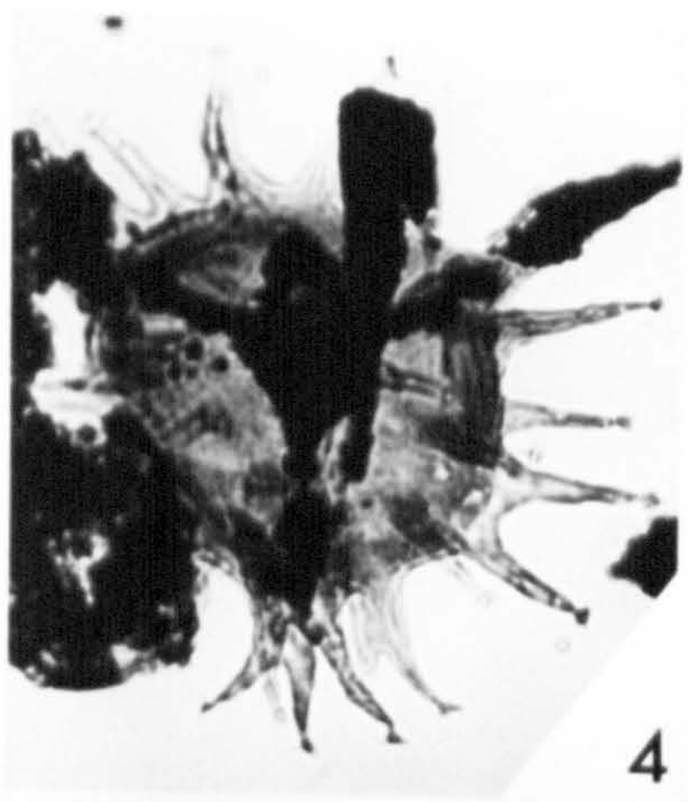

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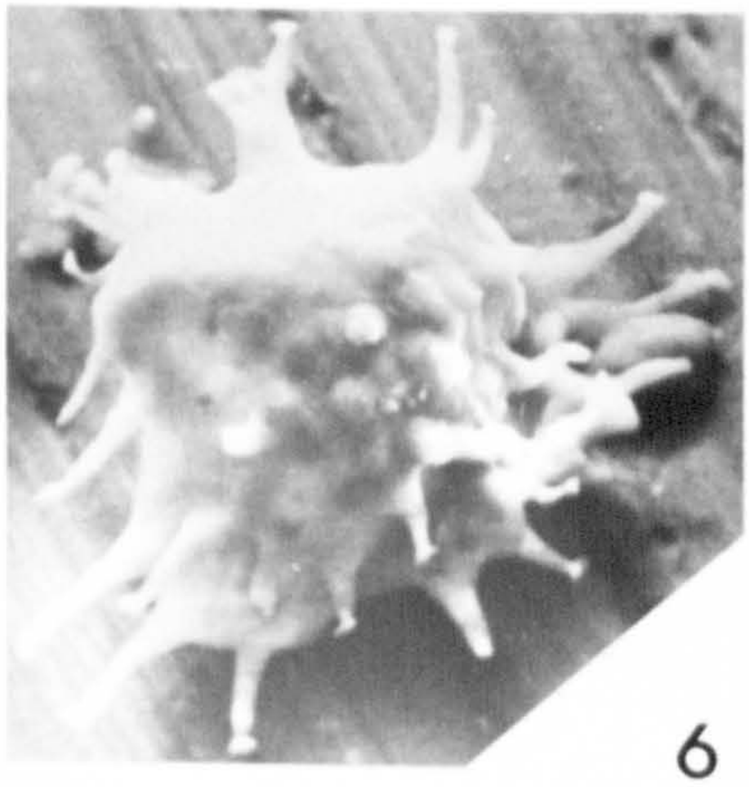

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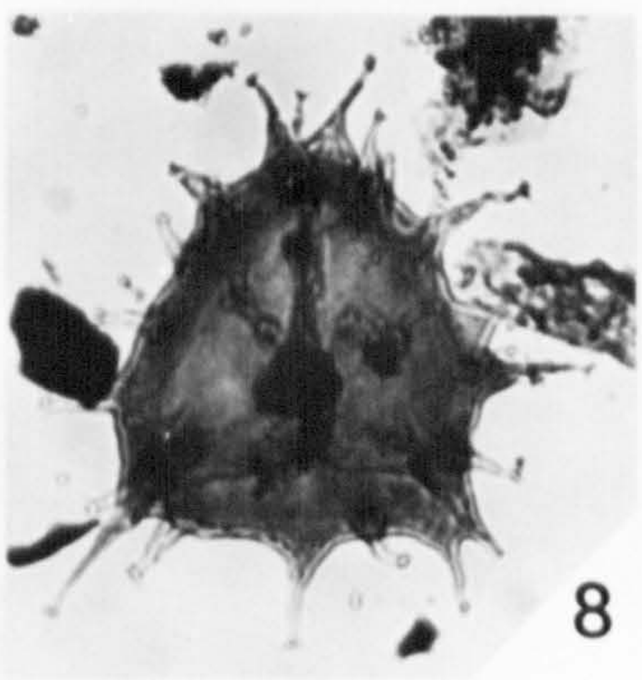

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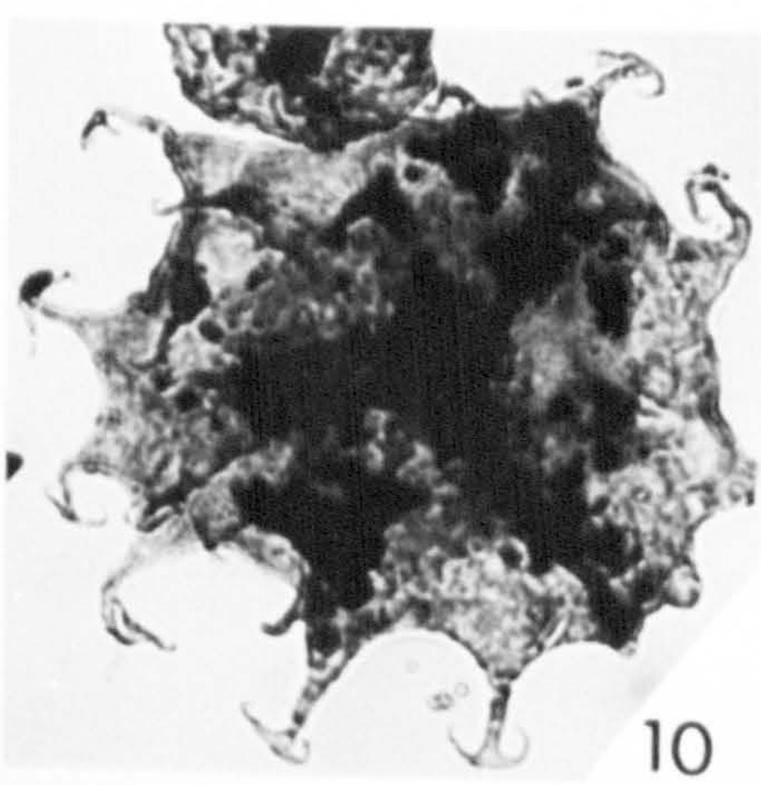

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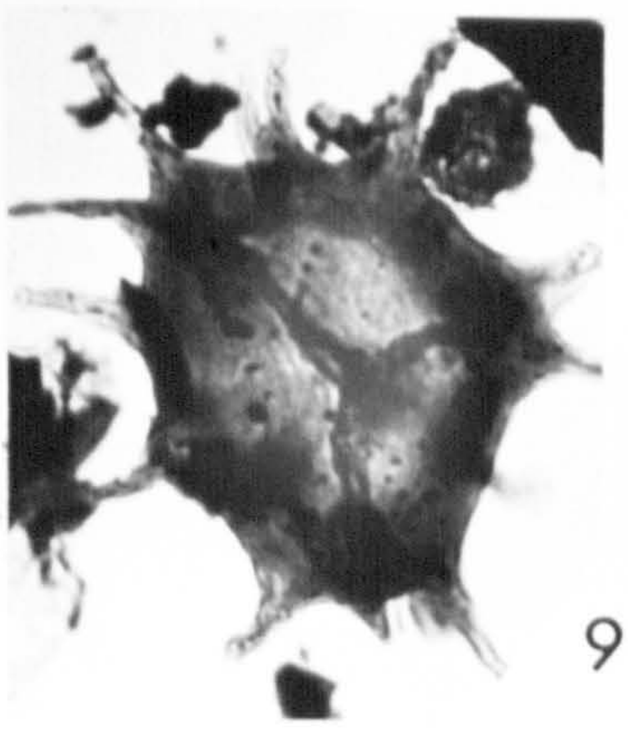

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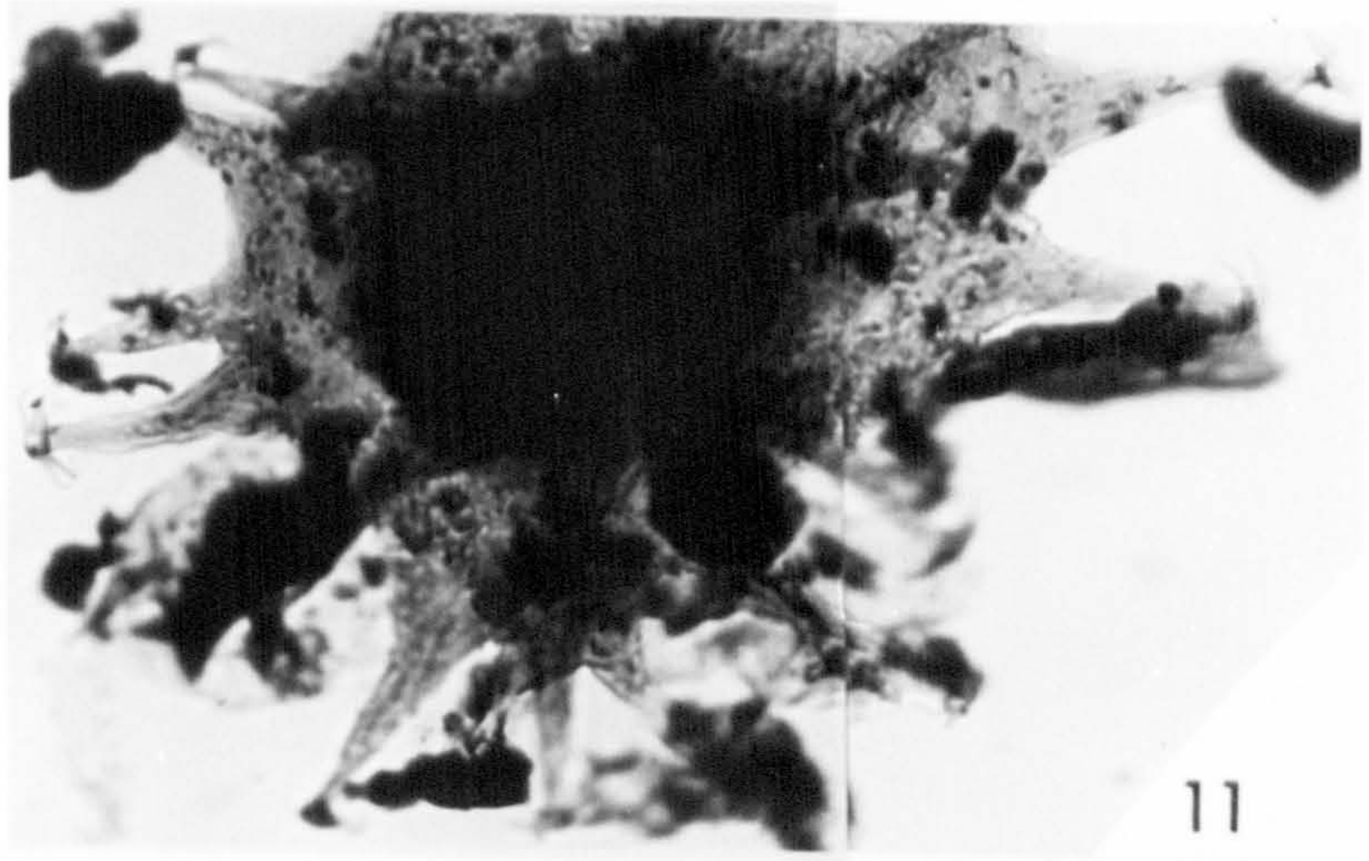

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PLATE I9

Figs. I-4. Ancyrospora multifurcata (Winslow) comb.nov.

I. Distal surface, SEM, X560. Cattaraugus Fm.

2. Detail of I, SEM, X2500. Cattaraugus Fm.

3. Proximal surface, SEM, XI100. Cattaraugus Fm.

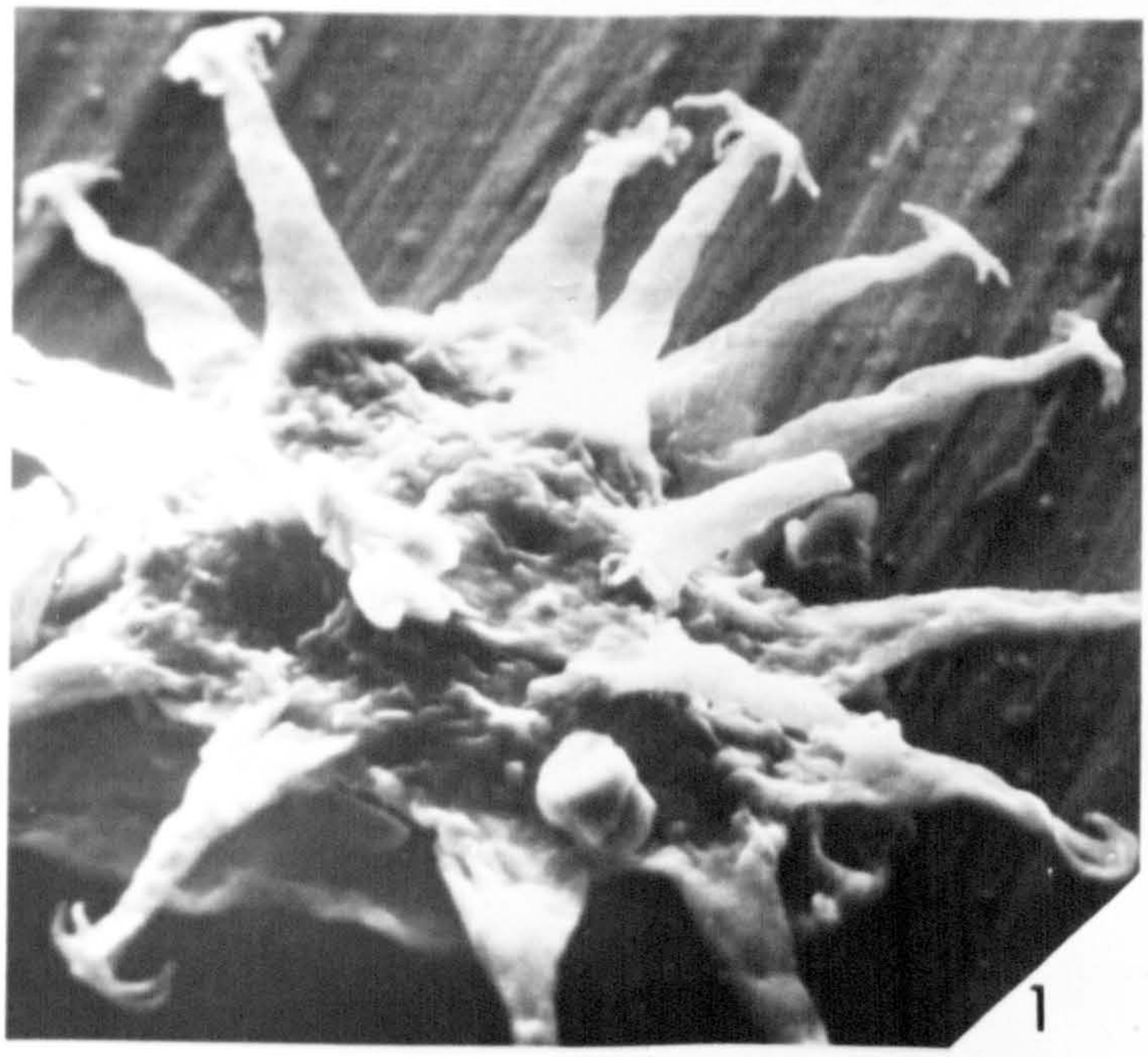
4. NY95A II I209742. Cattaraugus Fm.

Figs. 5-6. Ancyrospora neograndispinosa sp.nov.

5. Holotype, US8D 355 II30327. Ellicott Member.

6. US6E 302 III8356. Cattaraugus Fm.

PLATE 19



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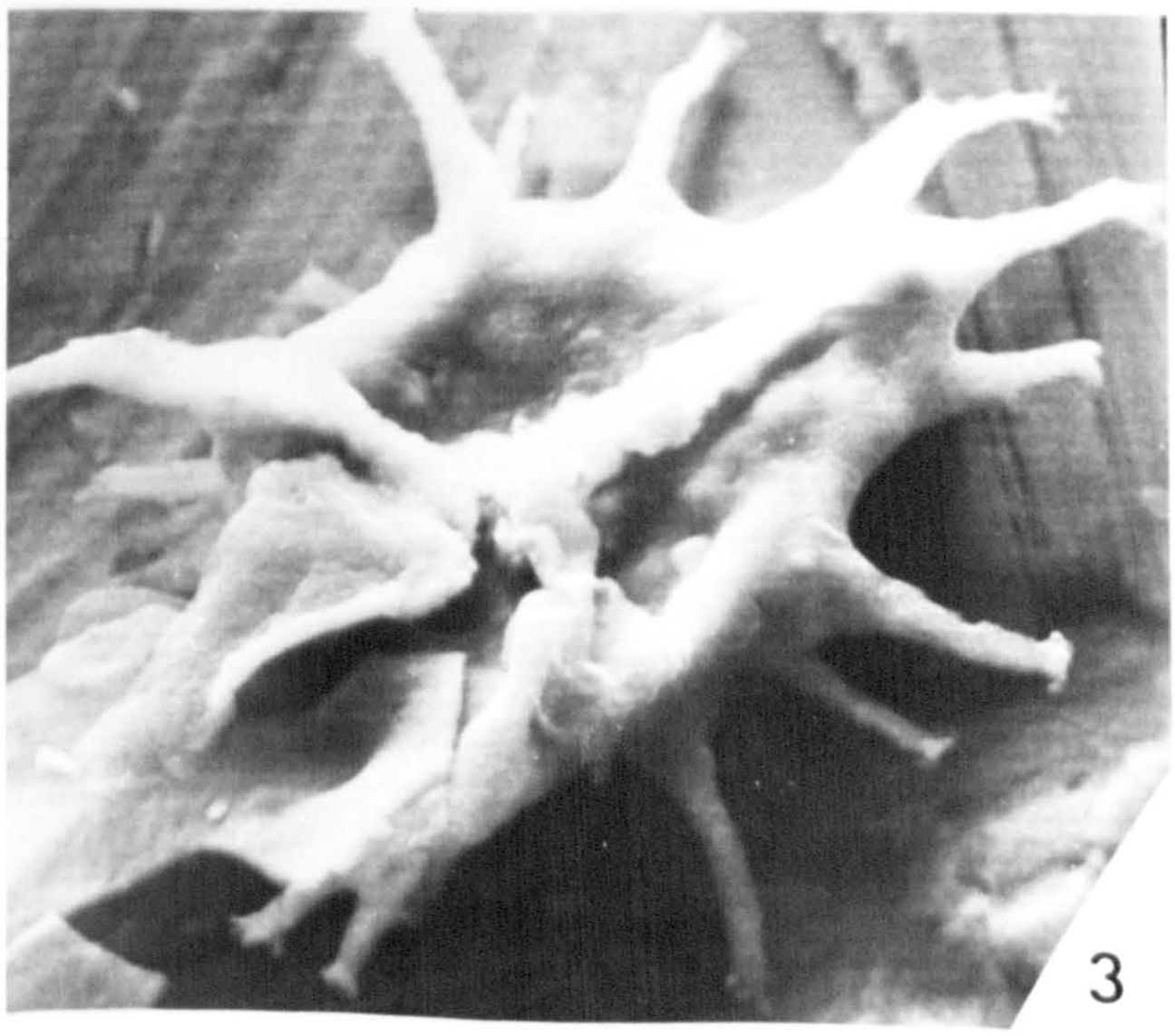

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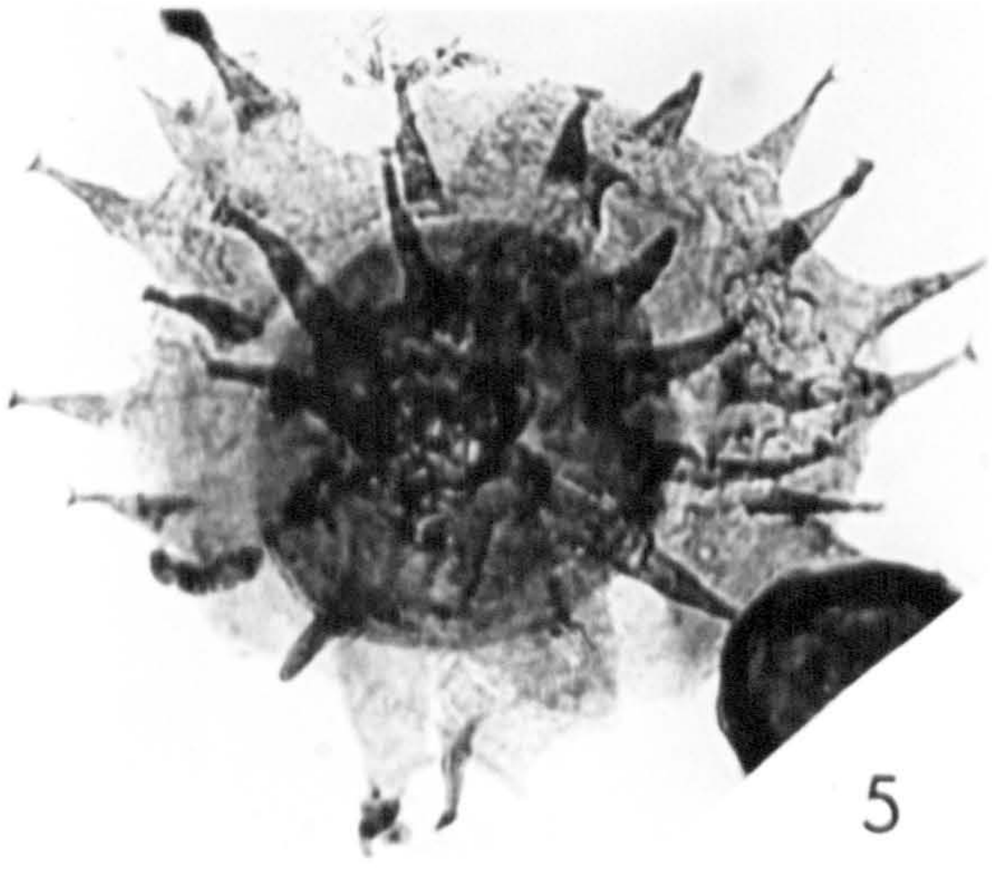

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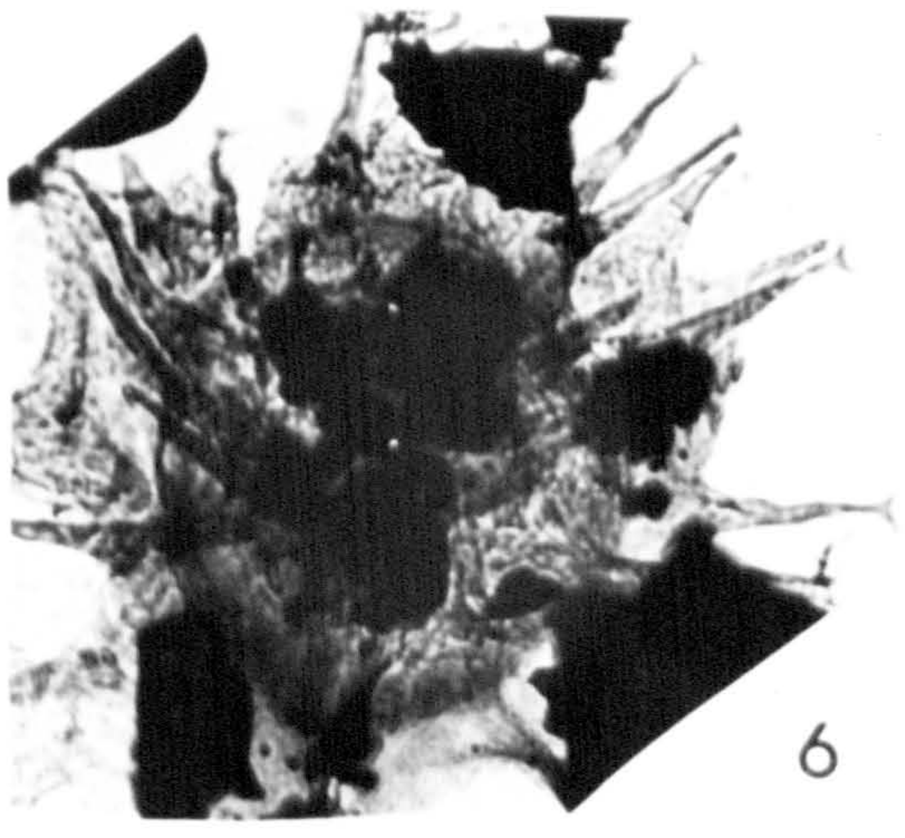

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PLATE 20

Fig. I. Hystricosporites mitratus Allen.
NY96H I48 I205345, X 300. Ellicott Member.

2. Hystricosporites porcatus (Winslow) Allen.
NY96G I38 I205625, X 300. Ellicott Member.

Figs. 3-5. Hystricosporites sp. aff. H. porrectus (Balme & Hassell) Allen.

3. US4A 200 II3458I, Dexterville Member.

4. USI2H 483 II9I579. Dunkirk Shale Member.

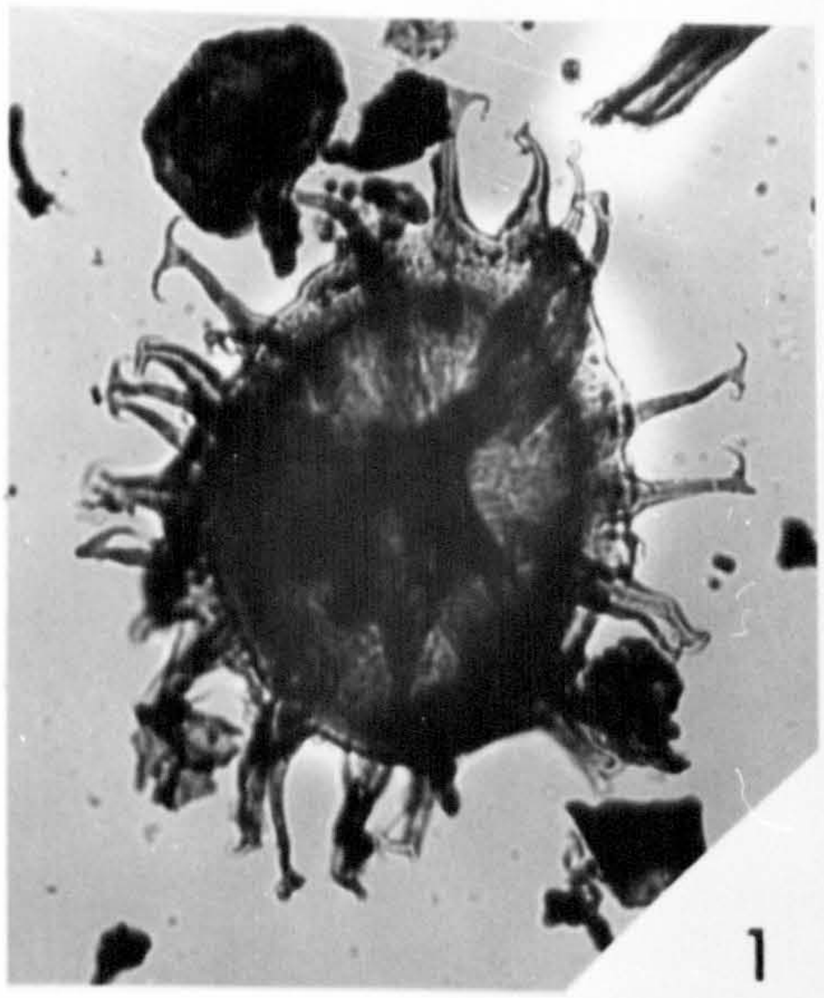
5. Section of specimen showing spines, I2X I67 I2I032I, Gowanda Shale Member.

Fig. 6. Spore type A,
US6E 297 II905I3. Cattaraugus Fm.

Fig. 7. Leiosphaeridia
US8A 332 II6I606. Ellicott Member.

Fig. 8. Leiosphaeridia
US8A 332 II26432. Ellicott Member.

PLATE 20



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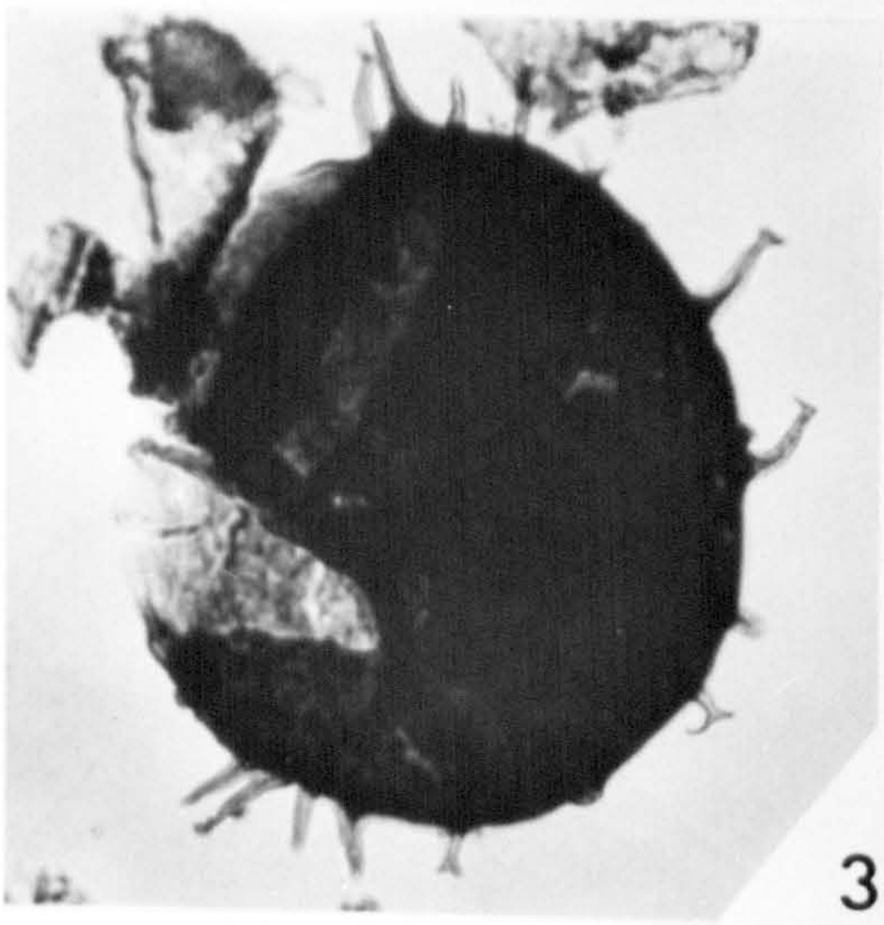

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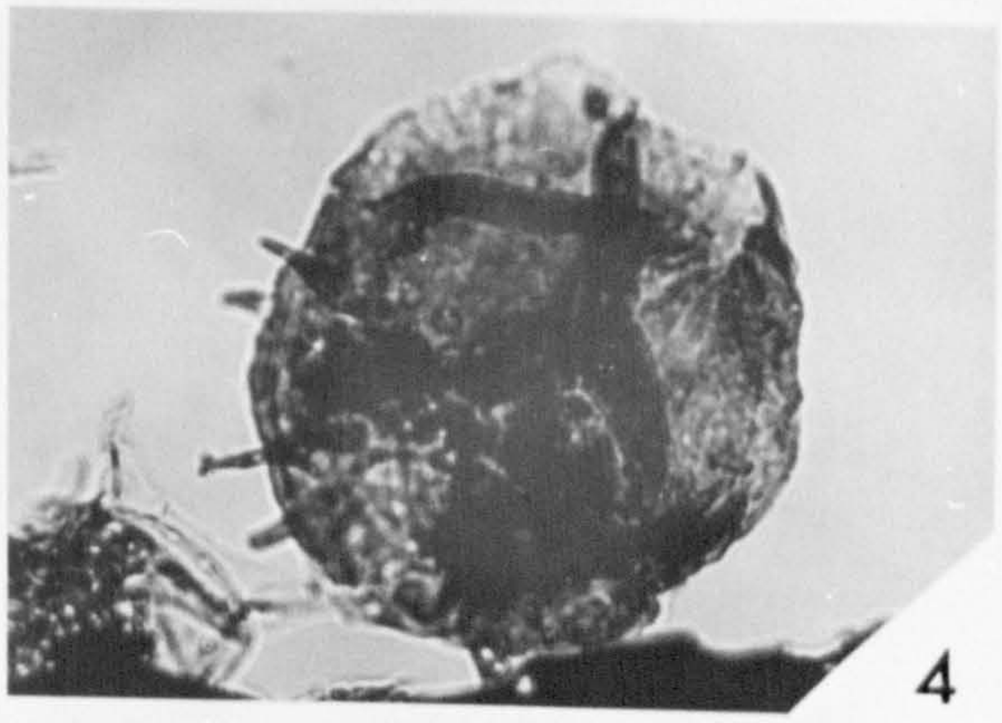

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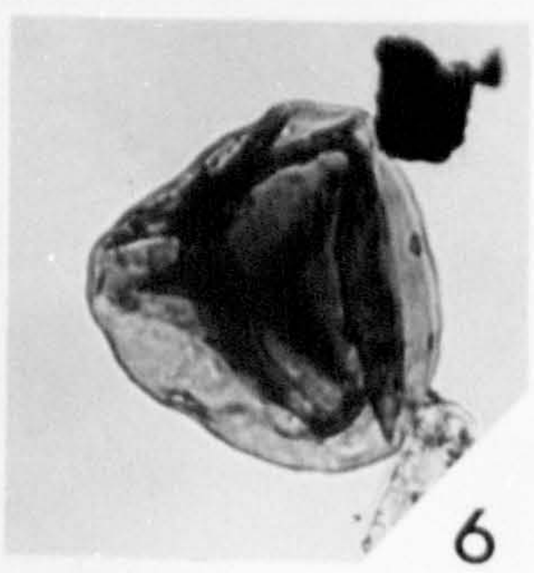

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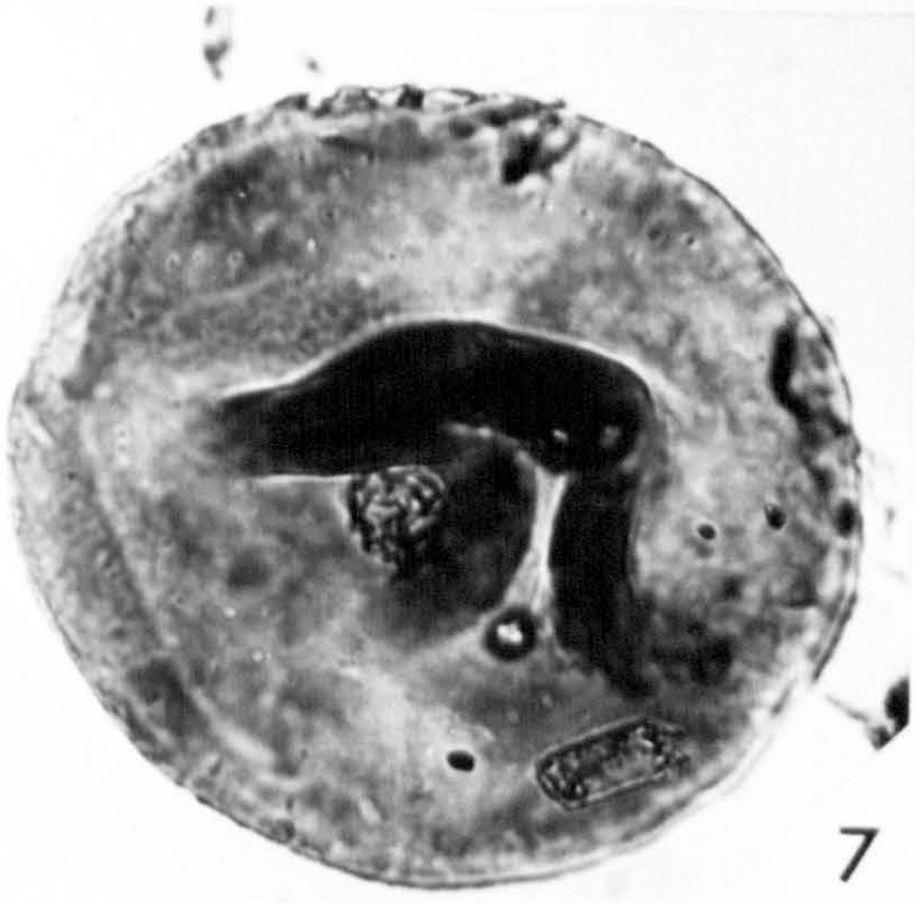

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PLATE 2I

Fig. I. Tasmanites sp.

US6E 299 I242498. Cattaraugus Formation.

Figs. 2-5. Cymatiosphaera sp.

2. US4E 235 II6I055. Dexterville Member.

3. US4E 235 III83I9. Dexterville Member.

4. US4E 235 III9309. Dexterville Member.

5. US4E 235 II083I2. Dexterville Member.

Fig. 6. Lophostridium cf. citrinum Downie

US8A 332 II58535. Ellicott Member.

Fig. 7. Veryhachium trispinosum Deunff.

US4A I98 I243519. Dexterville Member.

Fig. 8. Veryhachium lairdi Cramer

US4C 365 II29672. Dexterville Member.

Fig. 9. Micrhystridium cf. stellatum Deflandre.

US8B 34I I2II37. Ellicott Member.

Figs. I0-II. Electoreskos sp.

I0. US5 25I II4I66I. Ellicott Member.

II. US4E 23I I098549. Dexterville Member.

Fig. I2. Multiplicisphaeridium sp.

US4E 235 II5I296. Dexterville Member.

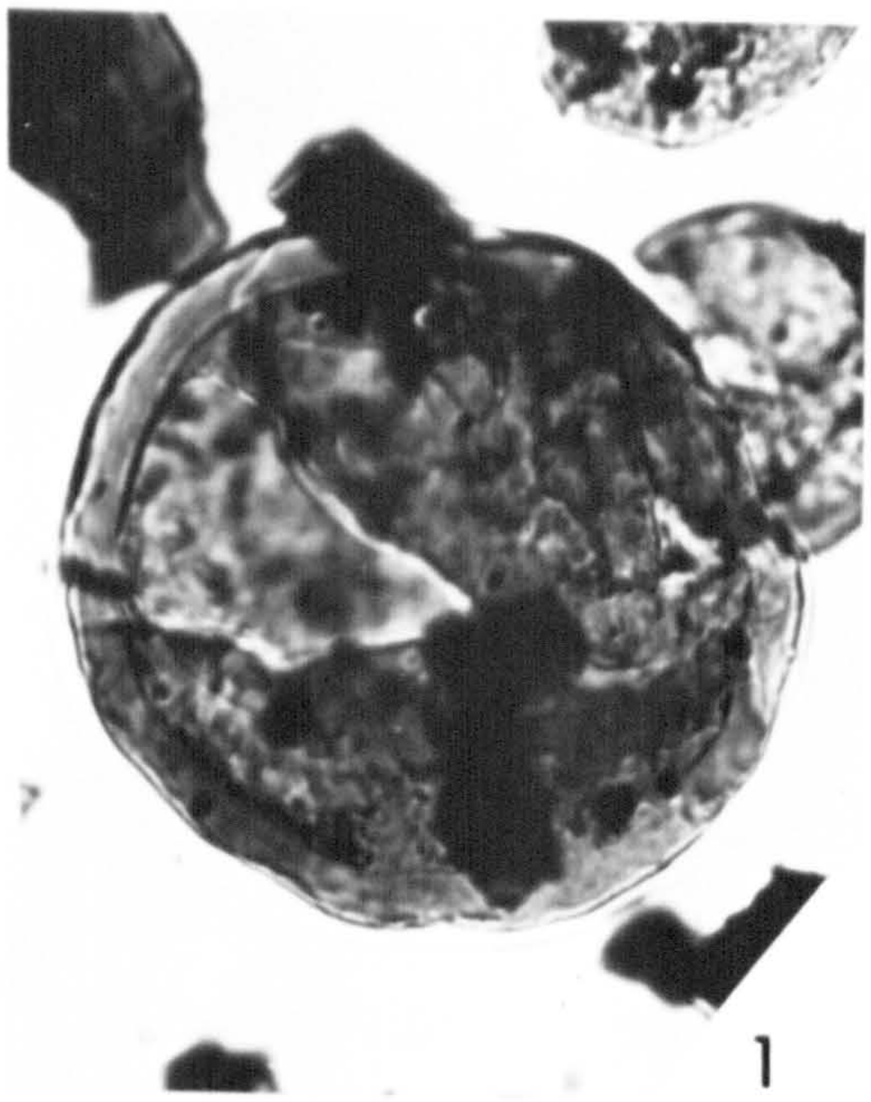
Fig. I3. Polydrixium sp.

USI2U I57 II58060. Gowanda Shale Member.

Fig. I4. Evittia sp.

US4E 235 III603I. Dexterville Member.

PLATE 21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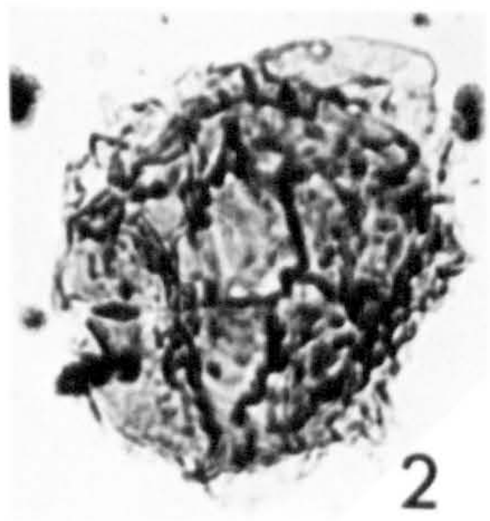
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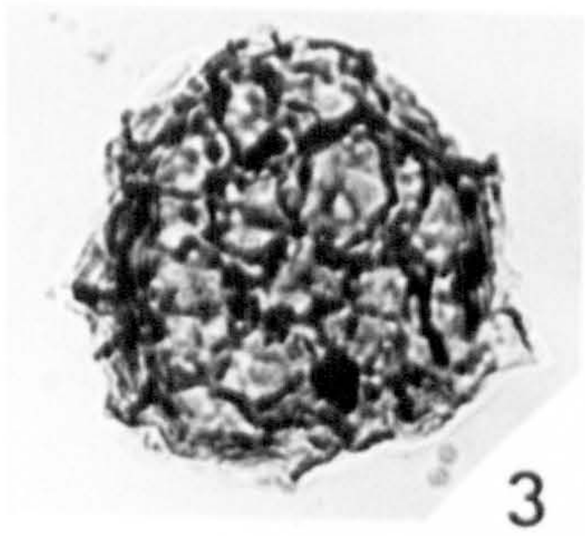
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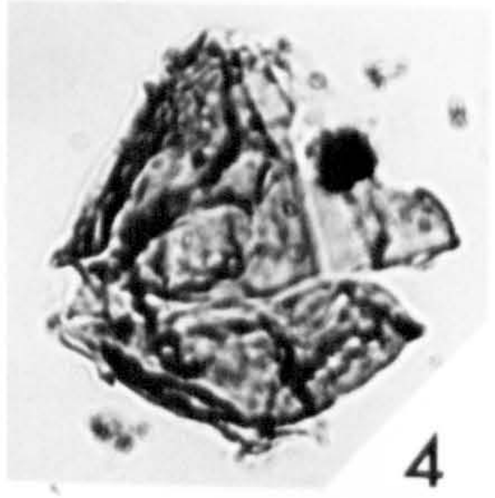
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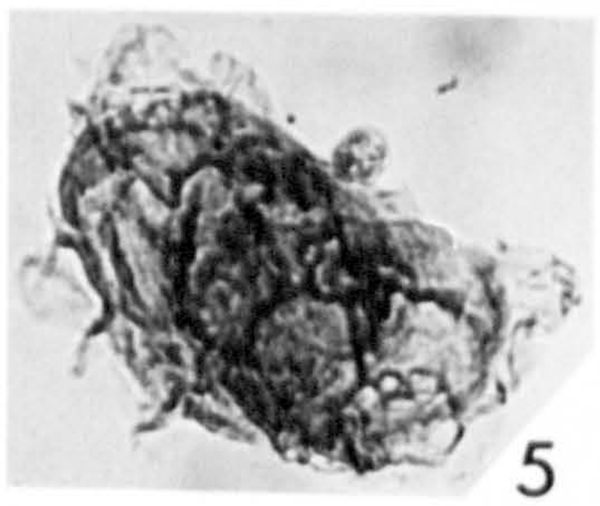
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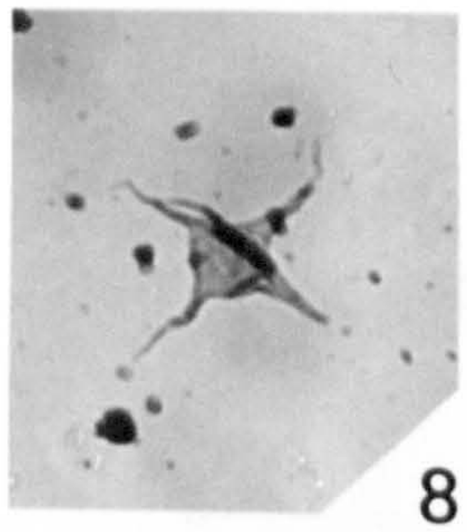
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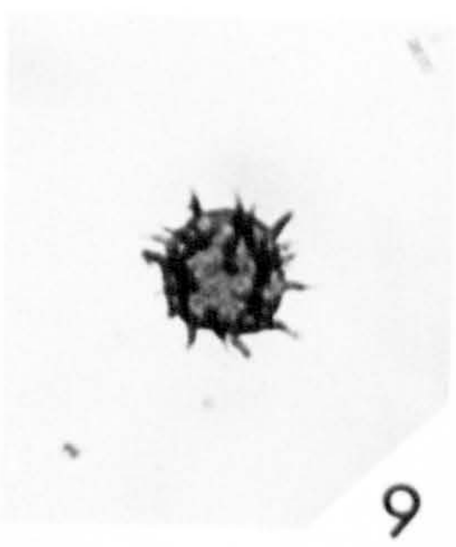
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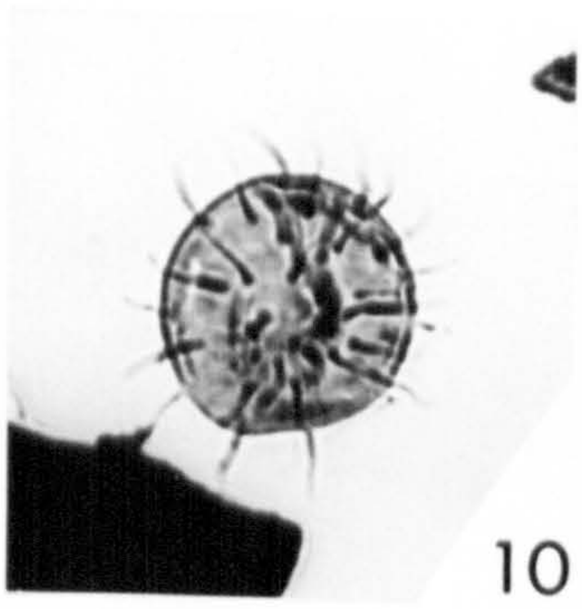
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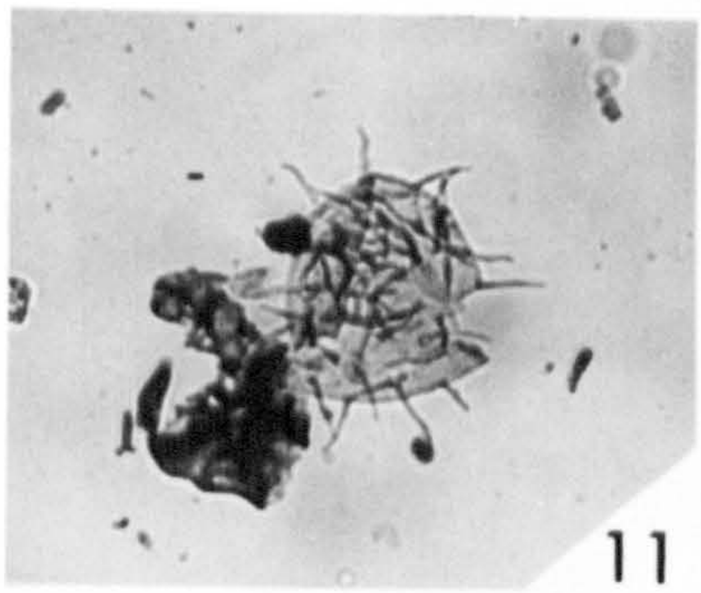
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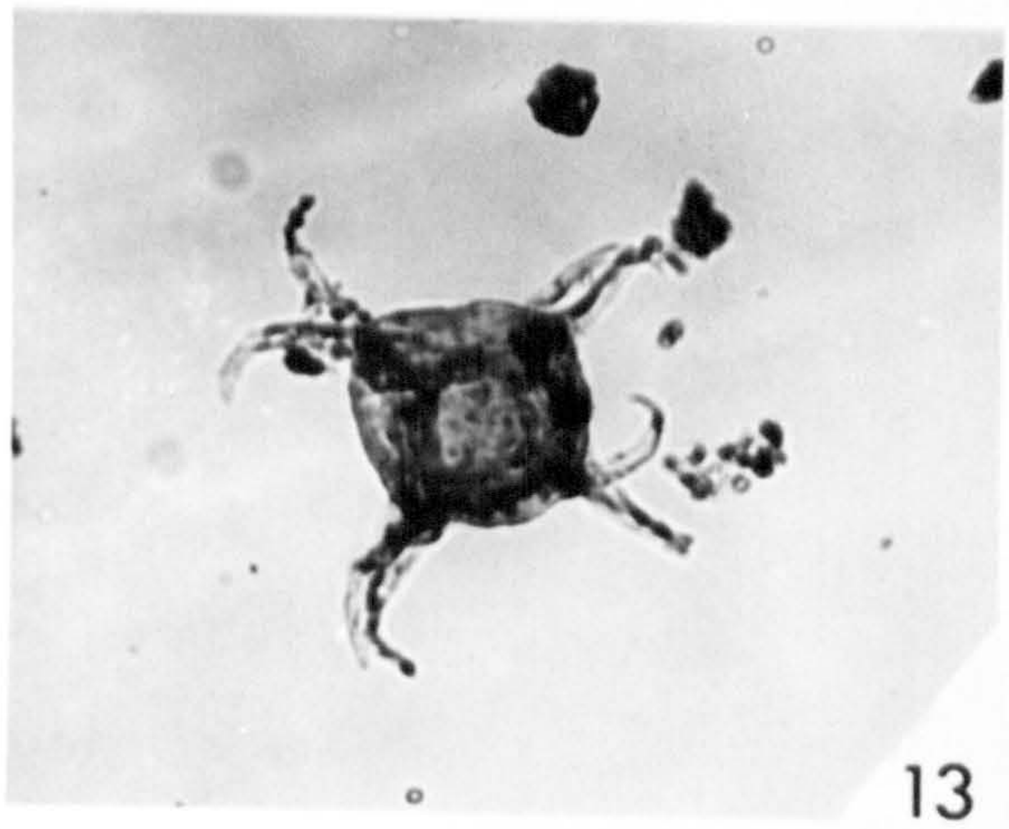
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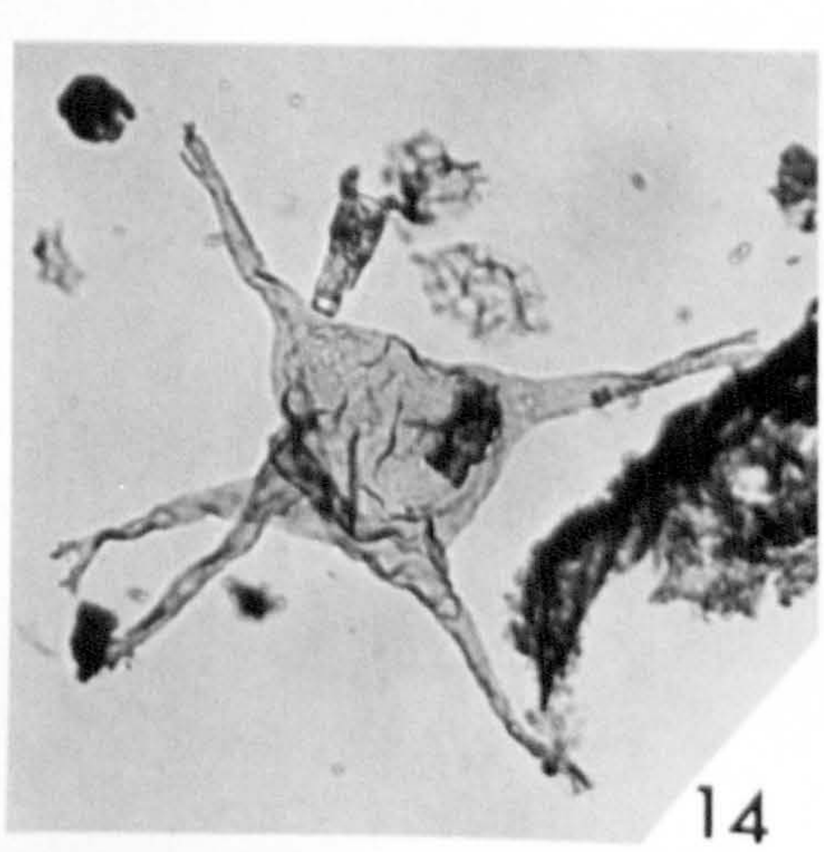
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PLATE 22.

Fig. I. Legenochitina sp.
USI2H I2I II7I48I. Dunkirk Shale Member.

Fig. 2. Angochitina sp.
USI2Y I7I II5I539. Laona Shale Member.

Fig. 3. cf. Hoegisphaera glabra Staplin
USI2N I42 I079486. South Wales Shale Member.

Fig. 4. Scolecodont sp.
US4A I98 II04060. Dexterville Member.

Figs. 5-7. Tracheids.
5. USI2V I60 II82263. Gowanda Shale Member.
6. US4B 206 II89712. Dexterville Member.
7. USI2L I34 II20602. South Wales Shale Member.

Fig. 8. Auroraspora spp. and plant fossils.
A sample from the Bush Hill Section.

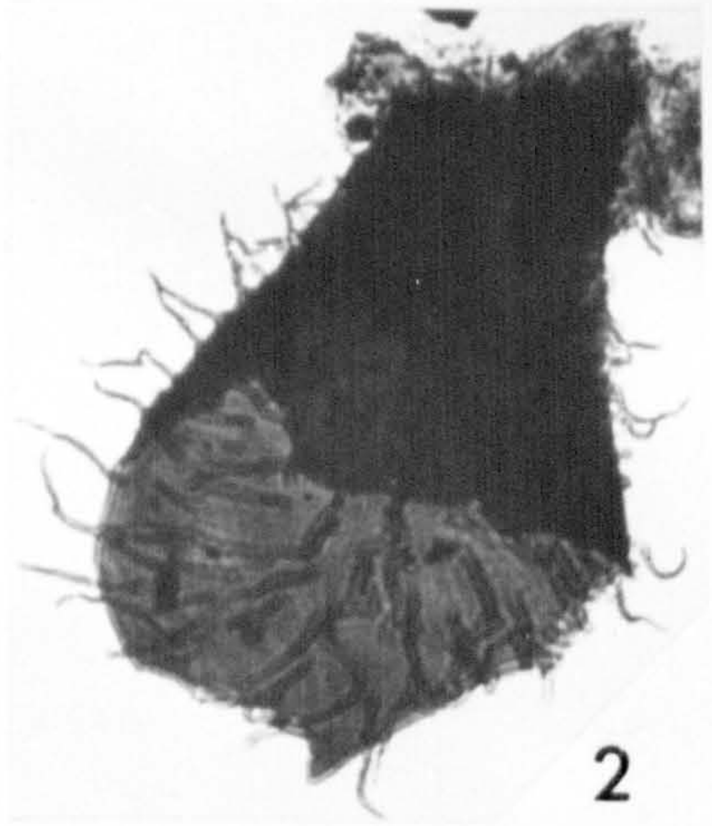
Fig. 9. Auroraspora spp. and plant fossils.
NY96C 74 II72558. Ellicott Member.

Fig. I0. Veryhachium spp. and plant fossils.
US8A 332 II42552. Ellicott Member.

Fig. II. Veryhachium spp. and Micristidium sp. with plant fossils.
US8A 332 II42559. Ellicott Member.

PLATE 22

1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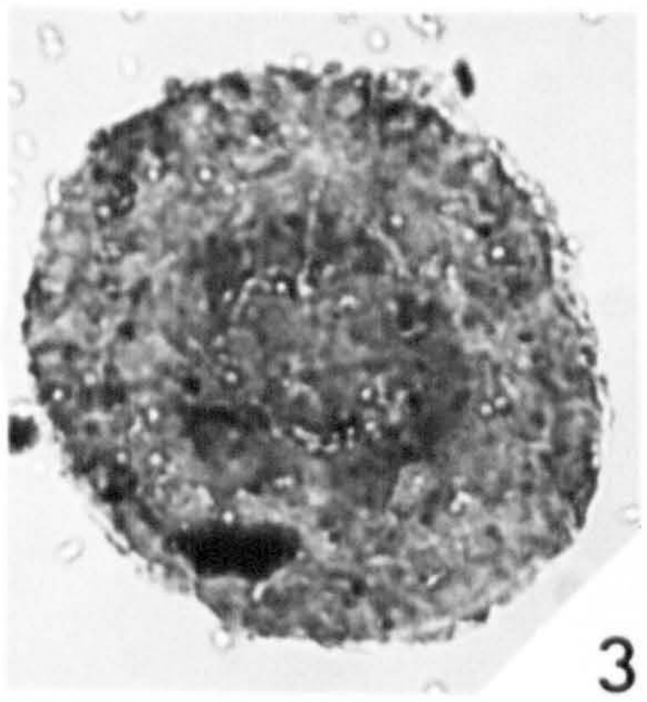
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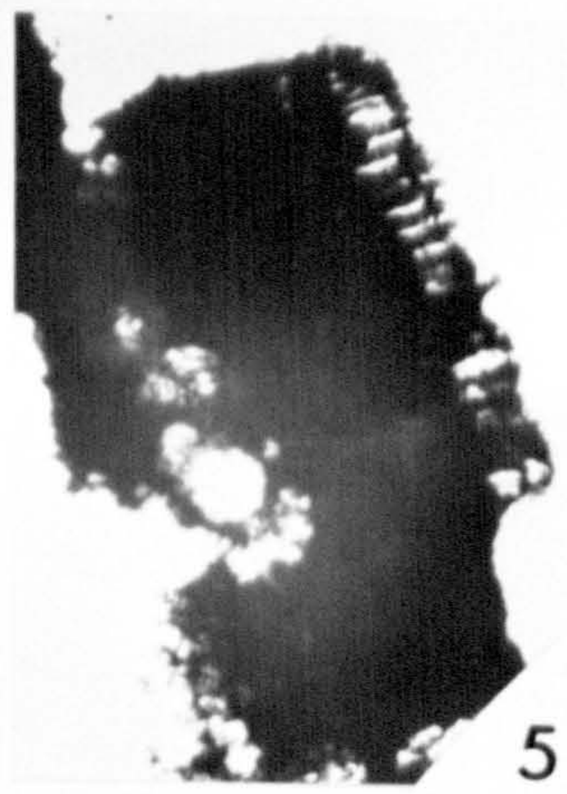
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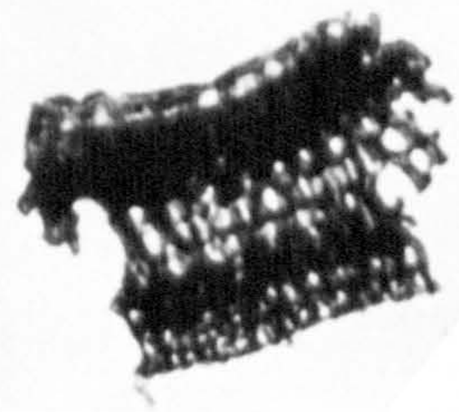
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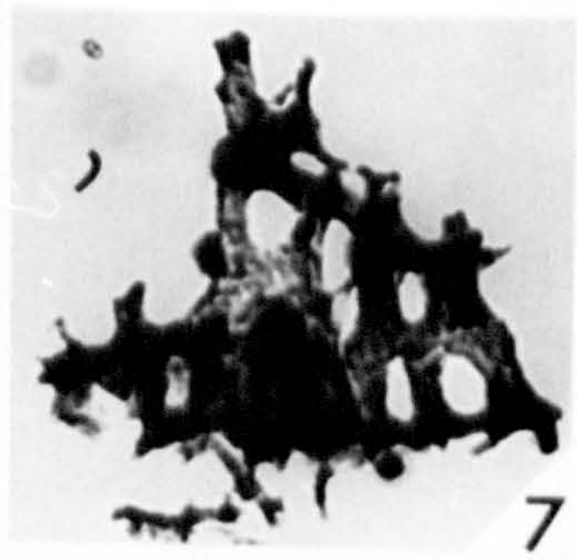
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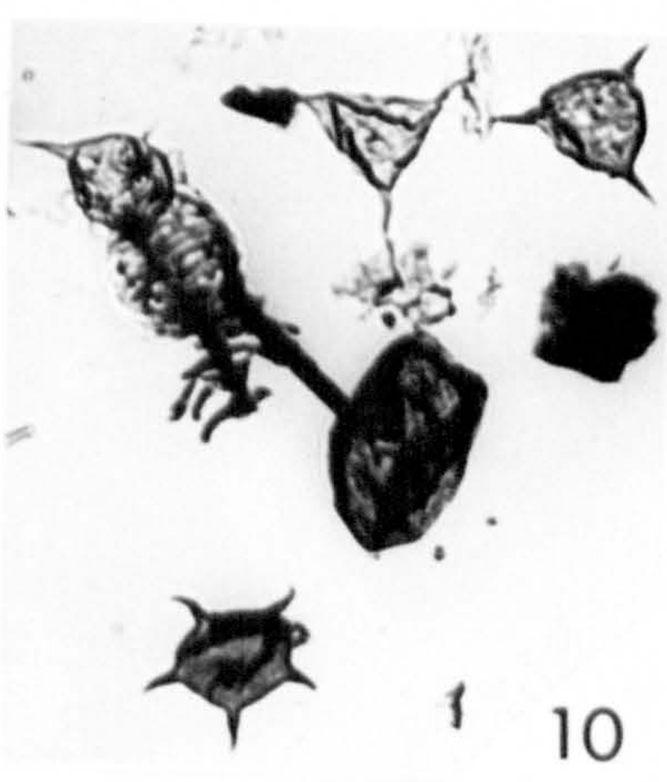
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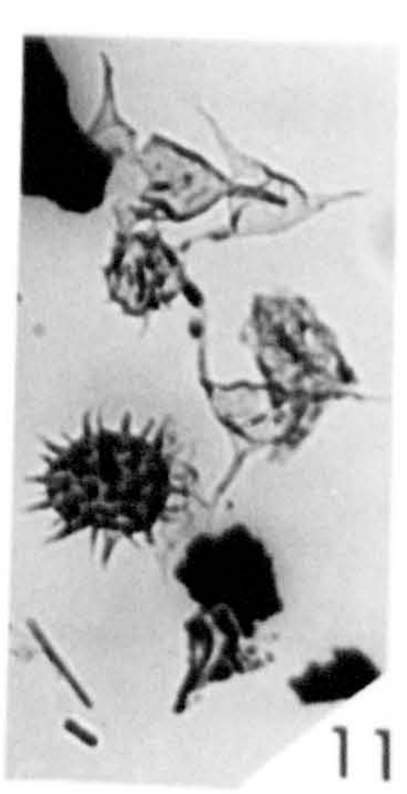
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APPENDIX (Locality and sample data)

Abbreviations: P.C.S.= Pipe Creek Shale; H.S.= Hanover Shale; D.S.= Dunkirk Shale; S.W.S.= South Wales Shale; G.S.= Gowanda Shale; L.S.= Laona Siltstone; W.S.= Westfield Shale; N.S.= Northeast Shale; D.= Dexterville; E.= Ellicott; C.= Cattaraugus Formation.

Microfossil data;
S, spore present; M, microplankton; C, citinozoa; P, plant fossils.

Sample no.	Location	Member	Microfossil data
WALNUT CREEK SECTION (COMPOSITE)			
USIIA	Hard black splintry shale with pyrite concretions; along the Lake Erie shore, approximately 5 Kms. Northeast of Dunkirk, Silver Creek quadrangle.	P.C.S.	S.M.& P.
USIIB	Grey shale with calcareous concretions; one metre above top of black shale (USIIA).	P.C.S.	S.M.& P.
USI2B	Grey shale with ellipsoidal calcareous concretions; base of cliff along the Lake Erie, near Point Gratiot (Dunkirk).	H.S.	S.M.C.&P.
USI2A	Green, grey and black shale with calcareous concretions; ½ metre above the base of cliff.	H.S.	S.M.C.&P.
USI2D	Olive-grey shale with calcareous concretions; one metre above USI2.	H.S.	S.M.C.&P.

Sample no.	Location	Member	Microfossil data
USI2E	Hard black shale; 2 metres above USI2D.	H.S.	S.M.& P.
USI2C	Hard greenish grey shale; ½ metre above I2E.	H.S.	S.M.C.
USI2F	Grey sandy siltstone with calcareous septaria; Lake Erie shore, ½ km. N.E. of Van Buren Point (Dunkirk).	D.S.	S.M.C.
USI2G	Grey shale with small calcareous concretions; 2 metres S. of I2F.	D.S.	S.M.
USI2H	Grey shale and siltstone with small calcareous concretions; I metre above USI2G.	D.S.	S.M.
USI2I	Grey shale with small silty concretions; I km. S. of Van Buren Point (Dunkirk).	S.W.S.	S.M.C.
USI2J	Grey shale and siltstone; I metre above USI2I.	S.W.S.	S.M.C.
USI2L	Black and grey shale; 2 metres above USI2J.	S.W.S.	S.M.C.
USI2K	Grey soft shale and hard ribs of silty shale with small calcareous concretions; I metre above USI2L.	S.W.S.	S.M.
USI2M	Grey siltstone; I km. E. of Dunkirk on route 39.	S.W.S.	S.M.
USI2N	Hard grey siltstone; I metre above USI2M.	S.W.S.	S.M.
USI2P	Black shale with grey siltstone; 2 metre above USI2M.	S.W.S.	S.M.

Sample no.	Location	Member	Microfossil data
USI2Q	Grey shale ; along the Lake Erie, I km. N.E. of Barcelona (Westfield quadrangle).	G.S.	S.M.C.
USI2R	Intercalations of black and grey shale; I metre above USI2Q.	G.S.	S.M.C.
USI2S	Grey shale; 3 metres above USI2Q.	G.S.	S.M.
USI2T	Hard grey silty shale; ½ km. S. of Portland on route 20.(Westfield quadrangle).	G.S.	S.M.
USI2U	Hard grey shale; I metre above USI2T.	G.S.	S.M.
USI2V	Grey shale with ellipsoidal calcareous concretions; along Walnut Creek I km. N. of Forestville.	G.S.	S.M.C.
USI2W	Black shale and siltstone ; along the Lake Erie shore, ½ km. N.E. of Barcelona.	L.S.	S.M.
USI2X	Hard siltstone and grey shale with calcarous nodules; I metre above USI2W.	L.S.	S.M.
USI2Z	Thin grey siltstone; I metre above USI2X.	L.S.	S.M.
USI2Y	Grey shale and siltstone with large elliptical calcareous nodules; I metre above USI2Z.	L.S.	S.M.
USI7L	Grey-green shale at the base of cliff along the Lake Erie shore, I km. S. W. of Barcelona.	W.S.	S.M.C.& P.
USI7S	Grey shale and fine grained siltstone; 2 metres above USI7L.	W.S.	S.M.C.& P.
USIOA	Soft grey shale and siltstone with hard sandy siltstone; along Canadaway Creek in Arkwright township; ½ km. S. of Shumla (Dunkirk).	N.S.	S.M.& P.

Sample no.	Location	Member	Microfossil data
USIOB	Soft grey and fine siltstone; 4 metres downstream from USIOA.	N.S.	S.M.& P.
USIOC	Soft grey shale and thin siltstone ; 8 metres downstream from USIOB.	N.S.	S.M.& P.
BRICK QUARRIES SECTION: (composite).			
US9	Soft grey shale interbedded with hard siltstone; Cherry Creek quadrangle, S. of Bont Well Hill road, just below small culvert under the road.	D.	S.M.& P.
US4A	Base of silty shale and plants; Jamestown quadrangle, Old Brick Quarries, E. of Jamestown.	D.	S.M.& P.
US4B	Interbedded light grey shale and siltstone containing bryozoan , brachiopods and plants; I metre above US4A.	D.	S.M.& P.
US4C	Crossed bedded silty sandstone with brachiopods and bryozoans; 2 metres above US4A.	D.	S.M.& P.
US4D	Interbedded fine grained grey-green silty sandstone and shale with small brachiopods; 9 metres above US4A.	D.	S.M.& P.
US4E	Olive-grey siltstone and shale; II metres above US4A.	D.	S.M.& P.
US4F	Grey-green shale interbedded with purple sandy silt and shale; 35 metres above US4A.	D.	S.M.& P.

Sample no.	Location	Member	Microfossil data
BUSH HILL SECTION (ARNOLD 1933, ARCHAEOPTERIS LOCALITY). Road cut on rout 6, approx. 3 kms. E. of Smethport, Pennsylvania. Grey-green siltstone overlain by green and red silt and flaggy sandstone.			
NY96A	Fined grained green siltstone with plants; base.	E.	S.& P.
NY96B	Khaki weathering sandy siltstone with plants; .IOI metre above NY96A.	E.	S.& P.
NY96C	Grey siltstone packed with plants, Archaeopteris; .254 metre above NY96A.	E.	S.& P.
NY96D	Grey siltstone; .533 metre above NY96A .	E.	S.& P.
NY96E	Fine grey-green siltstone overlain by sandy band and plants; .787 metre above NY96A.	E.	S.& P.
NY96F	Siltstone and abundant plants; 1.5 metre above NY96A.	E.	S.& P.
NY96G	Olive——grey, fine-granied siltstone; I.93 metre above NY96A.	E.	S.& P.
NY96H	Olive-grey shale; 2.I3 metre above NY96A.	E.	S.& P.
HAMLET QUADRANGLE SECTION,(COMPOSITE).			
US5	Soft siltstone and shale; Jamestown quadrangle, Stream bank exposure; just N. of Hunt Road, approx. 2 kms. W. of JamestownLine, Lakewood.	E.	S.M.& P.

Sample no.	Location	Member/ Formation	Microfossil data
US8A	Grey-green siltstone and silty sandstone; Hamlet (Cherry Creek) quadrangle, stream section, approx. ½ km. S. of Hamlet Town corners, 53.94 metres downstream.	E.	S.M.
US8B	Grey sandstone; I32.58 metres downstream of US8A.	E.	S.M.
US8C	Weathered grey-green siltstone and flaggey sandstone; I68 metres downstream of US8A.	E.	S.M.
US8D	Grey-green silt tone and flaggy sandstone.	E.	S.M.
POPE HOLLOW SECTION; ALONG BOUDDARY BETWEEN CARROLL AND SOUTH VALLY TOWNSHIPS, JAMESTOWN QUADRANGLE.			
US6A	Immediately above hard grey-green micaceous sandy siltstone; at the base of the section.	C.	S.M.& P.
US6B	Grey-green silty sandstone; I metre above US6A.	C.	S.M.& P.
US6C	Grey-green siltstone; 4 metres above US6A.	C.	S.M.& P.
US6D	Grey-green siltstone; IO metres above US6A.	C.	S.M.& P.
US6E	Light grey shale and siltstone; I5 metres above US6A.	C.	S.M.& P.
US6F	Grey shale interbedded with flaggy sandstone; 20 metres above US6A.	C.	S.M.&P.
US6G	Grey-green siltstone and thin hard silty sandstone; 25 metres above US6A.	C.	S.M.& P.
US6H	Interbedded light grey siltstone and medium grey sandstone; 30 metres above US6A.	C.	S.M.& P.

Sample no.	Location	Formation	Microfossil data
	LEWIS RUN SECTION, HANLEY QUARRIES, PENNSYLVANIA, (COMPOSITE).		
NY95A	Green siltstone; base of the section, channel sample.	C.	S.M.& P.
NY95B	Grey siltstone with plants passing up into purple siltstone	C.	S.M.& P.
NY95C	Interbedded hard green siltstone and micaceous sandstone containing stringers and plants; channel sample.	C.	S.M.& P.
US7	Grey micaceous silty sandstone; along the road which crosses the divide between Frews Run and the N. branch of Sawmill Run, in Carroll Township near the Chautauqua-Cattaraugus County line,	C.	S.M.& P.